COMPUTATIONAL FINANCE & RISK MANAGEMENT

UNIVERSITY *of* WASHINGTON

Department of Applied Mathematics

Introduction to Trading Systems

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Lecture references

- TradeAnalytics project page on R-forge:
  `http://r-forge.r-project.org/projects/blotter/`
  - documents and demos for:
    - blotter package
    - quantstrat package
      (specifically the `macd` and `Luxor` demo scripts)[†]

- Using quantstrat by Jan Humme & Brian Peterson
  `http://www.rinfinance.com/agenda/2013/workshop/Humme+Peterson.pdf`

- R-SIG-FINANCE:
  `https://stat.ethz.ch/mailman/listinfo/r-sig-finance`

[†] demos are located in the directory: `.../R-3.x.x/library/quantstrat/demo`

Outline

1. Baseline MACD strategy
2. Add stoploss order to MACD strategy
3. Add trailing stop to MACD strategy
4. Optimize stops
5. Optimal strategy setting
6. Wrap up

Outline

Multi-asset portfolios

Diversified portfolio of 4 exchange traded funds:

Symbol	**Sector**
ITOT	iShares Core S&P Total US Stock Market
AGG	iShares Core Total US Bond Market
VNQ	Vanguard REIT Index
GLD	SPDR Gold Shares

Fetch data and initialize financial instruments

```
library(quantstrat)
startDate <- '2010-01-01'   # start of data
endDate <-  '2013-07-31'    # end of data
symbols = c("ITOT", "AGG", "GLD", "VNQ")
Sys.setenv(TZ="UTC")        # set time zone
```

```
getSymbols(symbols, src='yahoo', index.class=c("POSIXt","POSIXct"),
  from=startDate, to=endDate)
for(symbol in symbols)
  assign(x=symbol,value=adjustOHLC(get(symbol),symbol.name=symbol))
```

```
initDate <- '2009-12-31'
initEq <- 1e6
currency("USD")
stock(symbols, currency="USD",multiplier=1)
```

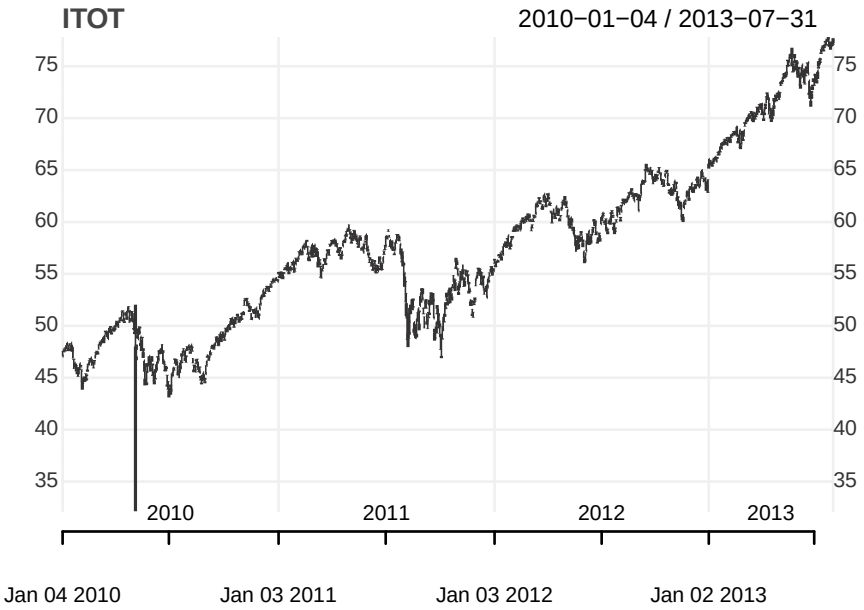
- Recommended that time zone be set to UTC
- Recommended that time series index is class POSIXct

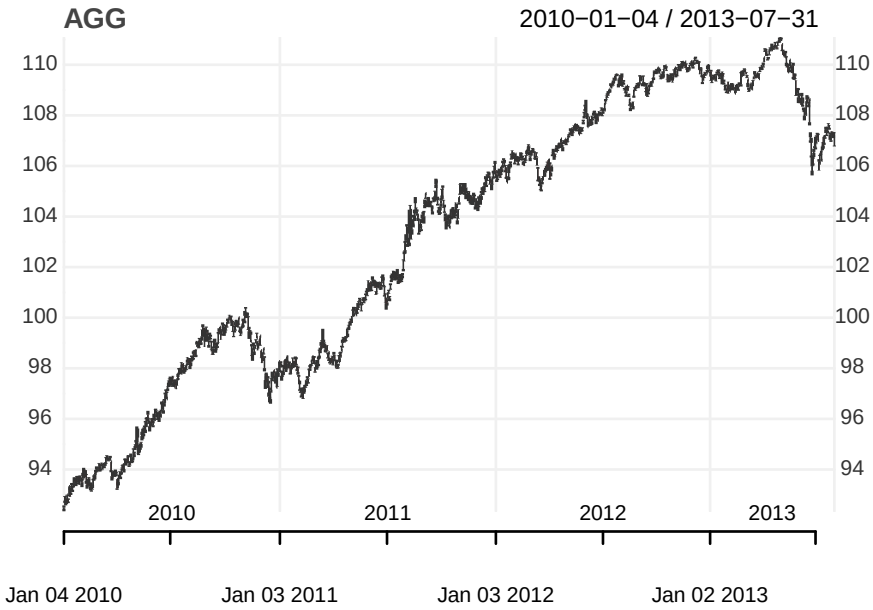
Plot time series of portfolio constituents

```
myTheme<-chart_theme()
myTheme$col$dn.col<-'lightblue'
myTheme$col$dn.border <- 'pink'
myTheme$col$up.border <- 'lightgray'
```

```
par(mfrow=c(2,2))
for(symbol in symbols)
{
  plot(chart_Series(get(symbol),name=symbol))
}
par(mfrow=c(1,1))
```

Four asset portfolio





MACD (Moving Average Convergence-Divergence)

- Trend-following momentum indicator
- Published by Gerald Appel in the late 1970
- MACD Calculation (defaults TTR calculation and values)
  - MACD = 100 * ((12-day EMA of close) / (26-day EMA of close) - 1)
  - MACD Signal Line = 9-day EMA of MACD
  - MACD histogram = MACD - Signal Line
- Interpretation
  - Buy/Sell when MACD Signal Line crosses 0

Long-only MACD momentum strategy

Buy rule:

- Buy long when the MACD signal crosses above 0

Exit rule:

- Sell when the MACD signal crosses below 0

Fixed-dollar order sizing function

This order sizing function adjusts the share quantity such that the transaction value is approximately equal to a pre-defined *tradesize*

```
osFixedDollar <- function(timestamp,orderqty, portfolio, symbol, ruletype, ...)
{
  ClosePrice <- as.numeric(Cl(mktdata[timestamp,]))
  orderqty <- round(tradeSize/ClosePrice,-2)
  return(orderqty)
}
```

- Function retrieves the current close price and sets order quantity as follows:

$$\text{orderqty} = \frac{\text{tradeSize}}{\mathit{ClosePrice}}$$

Define indicators and signals

```
strategy("macd", store=TRUE)
```

```
add.indicator("macd", name = "MACD",
  arguments = list(x=quote(Cl(mktdata))),label='osc')
```

```
add.signal("macd",name="sigThreshold",
  arguments=list(column="signal.osc",relationship="gt",threshold=0,cross=TRUE),
  label="signal.gt.zero")
```

```
add.signal("macd",name="sigThreshold",
  arguments=list(column="signal.osc",relationship="lt",threshold=0,cross=TRUE),
  label="signal.lt.zero")
```

Long entry rule

```
add.rule("macd",name='ruleSignal',
  arguments = list(sigcol="signal.gt.zero", sigval=TRUE,
    replace=FALSE,
    orderside='long',
    ordertype='market',
    orderqty=100,
    osFUN='osFixedDollar',
    orderset='ocolong'
  ),
  type='enter',
  label='LE'
)
```

- Belongs to orderset `ocolong`
  - Will be utilized later to support stop orders

Long exit rule

```
add.rule("macd",name='ruleSignal',
  arguments = list(sigcol="signal.lt.zero", sigval=TRUE,
    replace=TRUE,
    orderside='long',
    ordertype='market',
    orderqty='all',
    orderset='ocolong'
  ),
  type='exit',
  label='LX'
)
```

- Belongs to orderset `ocolong`
  - Will be utilized later to support stop orders

Data integrity check

- Verifies portfolio P&L and account summary P&L match
- Verifies no duplicate rows in summary objects

```
checkBlotterUpdate <- function(port.st,account.st,verbose=TRUE)
{
  ok <- TRUE
  p <- getPortfolio(port.st)
  a <- getAccount(account.st)
  syms <- names(p$symbols)
  port.tot <- sum(sapply(syms,FUN = function(x) eval(parse(
    text=paste("sum(p$symbols",x,"posPL.USD$Net.Trading.PL)",sep="$")))))
  port.sum.tot <- sum(p$summary$Net.Trading.PL)
  if( !isTRUE(all.equal(port.tot,port.sum.tot)) ) {
    ok <- FALSE
    if( verbose )
      print("portfolio P&L doesn't match sum of symbols P&L")
  }
  initEq <- as.numeric(first(a$summary$End.Eq))
  endEq <- as.numeric(last(a$summary$End.Eq))
  if( !isTRUE(all.equal(port.tot,endEq-initEq)) ) {
    ok <- FALSE
    if( verbose )
      print("portfolio P&L doesn't match account P&L")
  }
  if( sum(duplicated(index(p$summary))) ) {
    ok <- FALSE
    if( verbose )
      print("duplicate timestamps in portfolio summary")
  }
  if( sum(duplicated(index(a$summary))) ) {
    ok <- FALSE
    if( verbose )
      print("duplicate timestamps in account summary")
  }
  return(ok)
}
```

Initialize portfolio/account, apply strategy and verify

```
rm.strat("multi.macd.nostop") # remove portfolio, account, orderbook if re-run
initPortf(name="multi.macd.nostop", symbols, initDate=initDate)
initAcct(name="multi.macd.nostop", portfolios="multi.macd.nostop",
  initDate=initDate, initEq=initEq)
initOrders(portfolio="multi.macd.nostop", initDate=initDate)

fastMA = 12
slowMA = 26
signalMA = 9
maType="EMA"
tradeSize <- initEq/10

out<-applyStrategy("macd" , portfolios="multi.macd.nostop",
  parameters=list(nFast=fastMA, nSlow=slowMA, nSig=signalMA,maType=maType),
  verbose=TRUE)

updatePortf("multi.macd.nostop")
updateAcct("multi.macd.nostop")
updateEndEq("multi.macd.nostop")
```

```
checkBlotterUpdate("multi.macd.nostop","multi.macd.nostop")


## [1] TRUE
```

Performance results with no stoploss

```
equity.curve <- getAccount("multi.macd.nostop")$summary$End.Eq
returns.ns <- Return.calculate(equity.curve,"log")
table.AnnualizedReturns(returns.ns,geometric = FALSE)
```

```
##                             End.Eq
## Annualized Return           0.0193
## Annualized Std Dev          0.0313
## Annualized Sharpe (Rf=0%) 0.6174
```

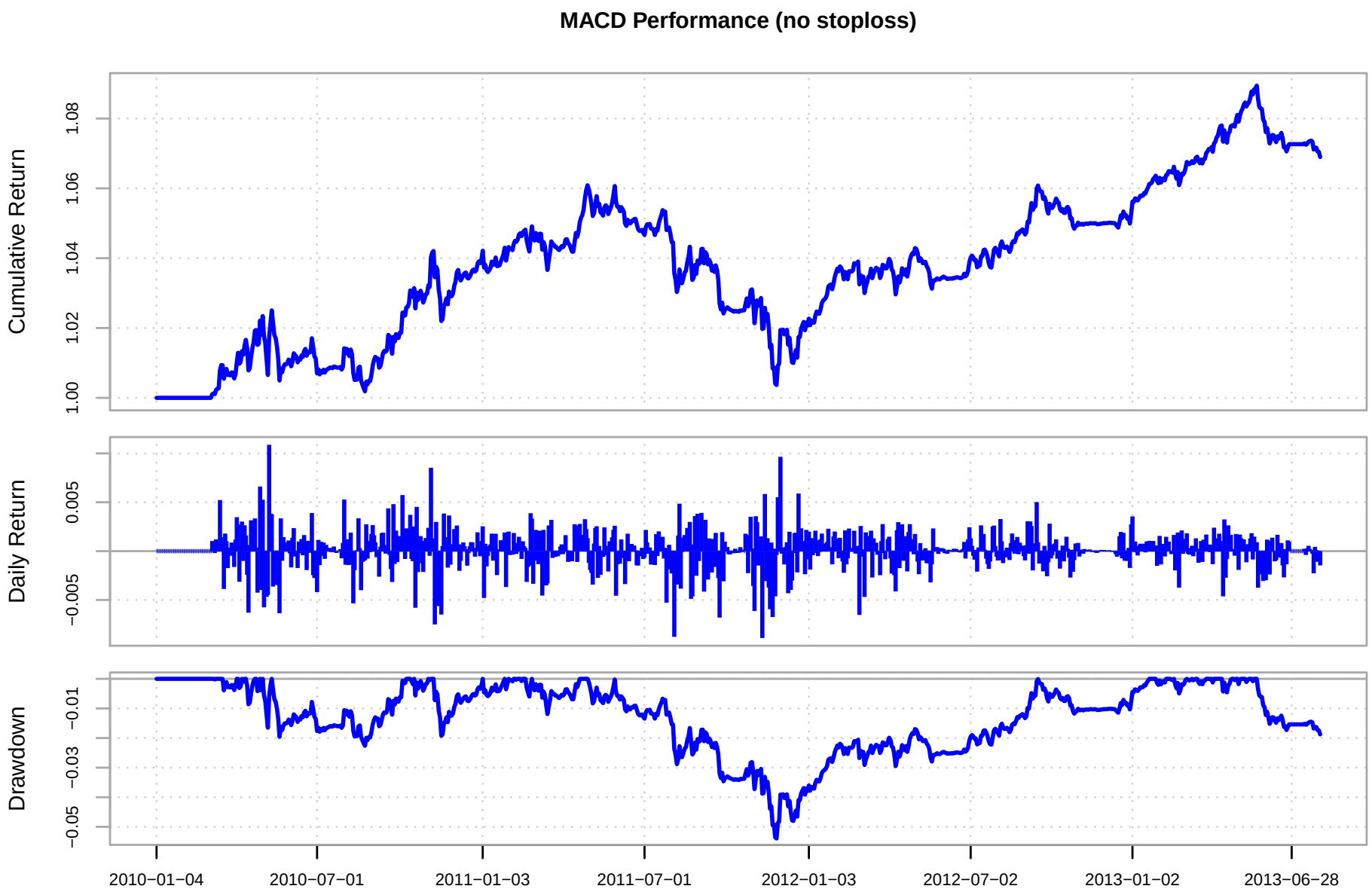
```
charts.PerformanceSummary(returns.ns,wealth.index=TRUE,geometric = FALSE,
  colorset="blue",xlab="",main="MACD Performance (no stoploss)",minor.ticks=FALSE)
```

```
PerformanceAnalytics:::textplot(t(tradeStats("multi.macd.nostop")))
```

```
chart.ME("multi.macd.nostop",'VNQ',type='MAE',scale='percent')
```

```
ob <- getOrderBook("multi.macd.nostop")$multi.macd.nostop$VNQ
ob.df <- data.frame(Date=time(ob),coredata(ob),stringsAsFactors=FALSE)
ob.df$Order.Price <- round(as.numeric(ob.df$Order.Price),3)
PerformanceAnalytics:::textplot(ob.df,show.rownames=F)
```

Performance summary with no stoploss



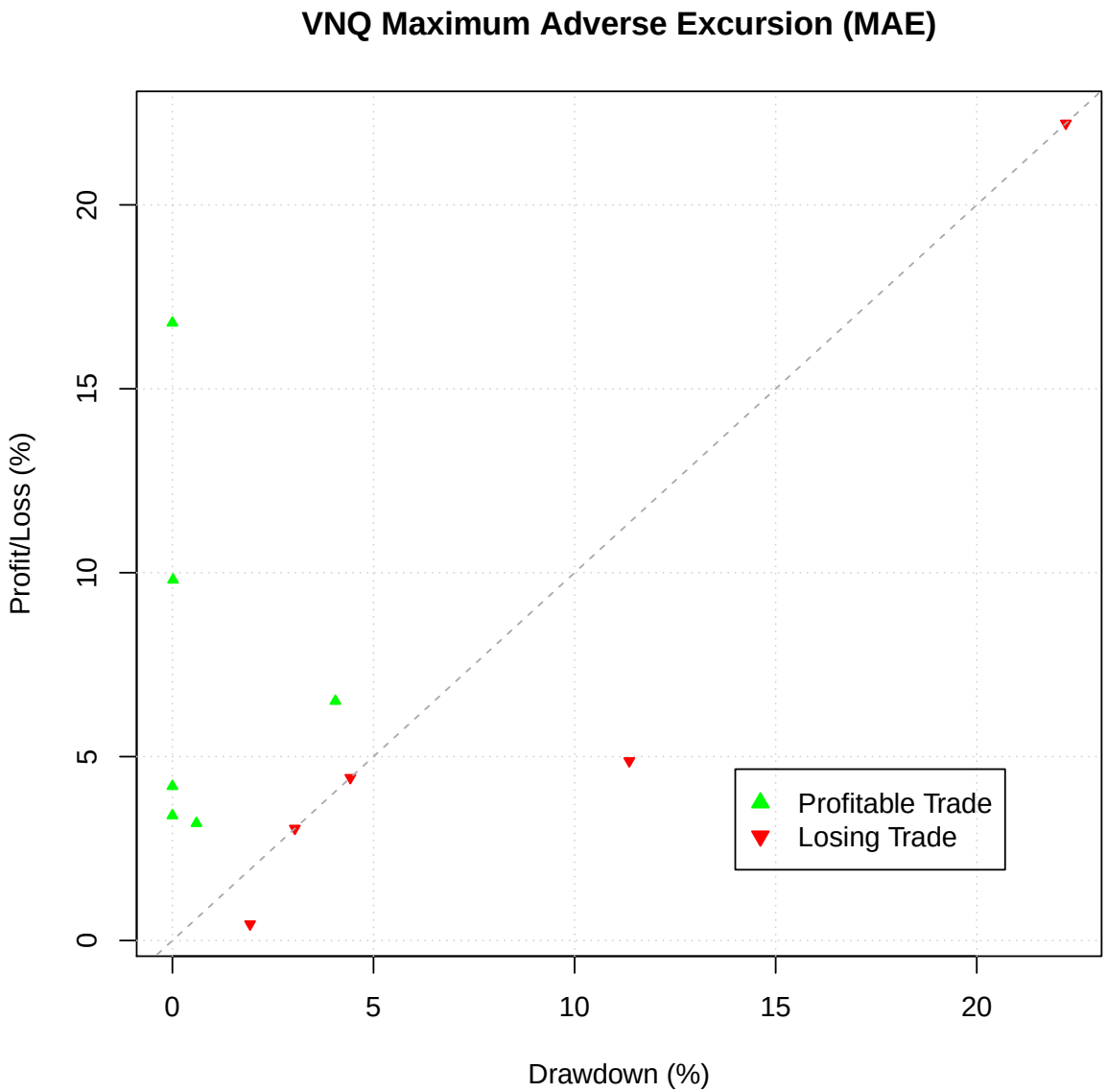
Trade stats for MACD strategy with no stoploss

	AGG	GLD	ITOT	VNQ
Portfolio	multi.macd.nostop	multi.macd.nostop	multi.macd.nostop	multi.macd.nostop
Symbol	AGG	GLD	ITOT	VNQ
Num.Txns	16	18	21	21
Num.Trades	8	9	10	10
Net.Trading.PL	12082.7662	15841.0130	34545.1189	8940.6918
Avg.Trade.PL	1510.3458	1760.1126	3399.9119	1343.4692
Med.Trade.PL	187.68348	2492.00000	2339.79841	3346.22656
Largest.Winner	6023.5203	10664.0000	17445.4703	16360.1052
Largest.Loser	−1019.4467	−9918.0000	−9161.5201	−22036.6577
Gross.Profits	13375.593	33139.013	51935.977	43778.801
Gross.Losses	−1292.8272	−17298.0000	−17936.8581	−30344.1093
Std.Dev.Trade.PL	2599.5428	6637.9832	8643.3157	10268.9104
Percent.Positive	62.500000	66.666667	60.000000	60.000000
Percent.Negative	37.500000	33.333333	40.000000	40.000000
Profit.Factor	10.3460022	1.9157714	2.8954891	1.4427446
Avg.Win.Trade	2675.1187	5523.1688	8655.9962	7296.4668
Med.Win.Trade	2122.1957	5821.5030	7613.1972	5437.1565
Avg.Losing.Trade	−430.94241	−5766.00000	−4484.21453	−7586.02733
Med.Losing.Trade	−250.04185	−4734.00000	−3318.00511	−3926.30823
Avg.Daily.PL	1510.3458	1760.1126	3399.9119	1343.4692
Med.Daily.PL	187.68348	2492.00000	2339.79841	3346.22656
Std.Dev.Daily.PL	2599.5428	6637.9832	8643.3157	10268.9104
Ann.Sharpe	9.2231587	4.2092485	6.2443546	2.0768427
Max.Drawdown	−2921.0877	−34380.9940	−18323.7820	−41204.2080
Profit.To.Max.Draw	4.13639279	0.46074913	1.88526140	0.21698492
Avg.WinLoss.Ratio	6.20760133	0.95788568	1.93032606	0.96182976
Med.WinLoss.Ratio	8.4873620	1.2297218	2.2945104	1.3848012
Max.Equity	13078.139	42398.007	38651.851	26969.252
Min.Equity	−168.98432	−3996.00000	−2933.01693	−23526.00567
End.Equity	12082.7662	15841.0130	34545.1189	8940.6918

Order book for VNQ no stoploss

	Order.Qty	Order.Price	Order.Type	Order.Side	Order.Threshold	Order.Status	Order.StatusTime	Prefer	Order.Set	Txn.Fees	Rule	Time.In.Force
2010−03−04 00:00:00	2500	39.816	market	long		closed	2010−03−05 00:00:00		ocolong	0	LE	
2010−05−24 00:00:00	all	41.953	market	long		closed	2010−05−25 00:00:00		ocolong	0	LX	
2010−06−23 00:00:00	2300	43.897	market	long		closed	2010−06−24 00:00:00		ocolong	0	LE	
2010−06−29 00:00:00	all	42.107	market	long		closed	2010−06−30 00:00:00		ocolong	0	LX	
2010−07−27 00:00:00	2200	45.862	market	long		closed	2010−07−28 00:00:00		ocolong	0	LE	
2010−11−23 00:00:00	all	47.830	market	long		closed	2010−11−24 00:00:00		ocolong	0	LX	
2010−12−27 00:00:00	2000	50.273	market	long		closed	2010−12−28 00:00:00		ocolong	0	LE	
2011−03−23 00:00:00	all	51.864	market	long		closed	2011−03−24 00:00:00		ocolong	0	LX	
2011−04−01 00:00:00	1900	53.917	market	long		closed	2011−04−04 00:00:00		ocolong	0	LE	
2011−06−14 00:00:00	all	54.516	market	long		closed	2011−06−15 00:00:00		ocolong	0	LX	
2011−07−06 00:00:00	1700	57.627	market	long		closed	2011−07−07 00:00:00		ocolong	0	LE	
2011−08−05 00:00:00	all	49.706	market	long		closed	2011−08−08 00:00:00		ocolong	0	LX	
2011−10−27 00:00:00	1800	55.017	market	long		closed	2011−10−28 00:00:00		ocolong	0	LE	
2011−11−29 00:00:00	all	50.104	market	long		closed	2011−11−30 00:00:00		ocolong	0	LX	
2011−12−12 00:00:00	1900	51.886	market	long		closed	2011−12−13 00:00:00		ocolong	0	LE	
2012−05−24 00:00:00	all	60.126	market	long		closed	2012−05−25 00:00:00		ocolong	0	LX	
2012−06−25 00:00:00	1700	60.361	market	long		closed	2012−06−26 00:00:00		ocolong	0	LE	
2012−10−01 00:00:00	all	62.628	market	long		closed	2012−10−02 00:00:00		ocolong	0	LX	
2012−12−12 00:00:00	1600	63.279	market	long		closed	2012−12−13 00:00:00		ocolong	0	LE	
2013−06−04 00:00:00	all	69.525	market	long		closed	2013−06−05 00:00:00		ocolong	0	LX	
2013−07−19 00:00:00	1400	72.330	market	long		closed	2013−07−22 00:00:00		ocolong	0	LE	

Maximum adverse excursion for VNQ no stoploss



Outline

Long-only MACD momentum strategy

Buy rule:

- Buy long when the MACD signal crosses above 0

Exit rule:

- Sell when the MACD signal crosses below 0

Stop rule:

- Stop loss set at 0.05% below entry price

Ordersets and order chains

To implement stop-loss or trailing-stop orders, quantstrat utilizes the concept of ordersets and order chains:

orderset	An orderset is a collection of OCO orders
OCO order	One-Cancels-Other (OCO) orders are grouped orders such that when one is filled, all others in the orderset are cancelled
order chain	An order chain defines an order (child) which will be created when another order (parent) is filled

The add.rule function

The function add.rule adds a rule to a strategy

```
args(add.rule)

## function (strategy, name, arguments, parameters = NULL, label = NULL,
##     type = c(NULL, "risk", "order", "rebalance", "exit", "enter",
##         "chain"), parent = NULL, ..., enabled = TRUE, indexnum = NULL,
##     path.dep = TRUE, timespan = NULL, store = FALSE, storefun = TRUE)
## NULL
```

Main arguments:

strategy	strategy object
name	name of the rule (typically ruleSignal)
arguments	arguments to be passed to the rule function
type	type of rule ("risk","order","rebalance","exit","enter")

The ruleSignal function

ruleSignal is the default rule to generate a trade order on a signal

```
args(ruleSignal)

## function (mktdata = mktdata, timestamp, sigcol, sigval, orderqty = 0,
##     ordertype, orderside = NULL, orderset = NULL, threshold = NULL,
##     tmult = FALSE, replace = TRUE, delay = 1e-04, osFUN = "osNoOp",
##     pricemethod = c("market", "opside", "active"), portfolio,
##     symbol, ..., ruletype, TxnFees = 0, prefer = NULL, sethold = FALSE,
##     label = "", order.price = NULL, chain.price = NULL, time.in.force = "")
## NULL
```

Main arguments:

sigcol	column name to check for signal
sigval	signal value to match
orderqty	quantity for order or 'all', modified by osFUN
ordertype	"market","limit","stoplimit","stoptrailing","iceberg"
orderside	"long", "short", or NULL
osFUN	function or name of order sizing function (default is osNoOp)

The ruleSignal function

Stoplimit-related arguments:

orderset	A tag identifying the orderset; if one order of the set is filled, all others are canceled
threshold	A numeric or name of indicator column in mktdata
tmult	If TRUE, threshold is a percent multiplier for price, not a scalar
replace	If an orderset is specified and replace=TRUE, all open orders for the orderset will be replaced
prefer	The preferred order price

Long stop loss

```
stopLossPercent <- 0.05
```

```
add.rule("macd",name='ruleSignal',
  arguments = list(sigcol="signal.gt.zero", sigval=TRUE,
    replace=FALSE,
    orderside='long',
    ordertype='stoplimit',
    tmult=TRUE,
    threshold=quote( stopLossPercent ),
    orderqty='all',
    orderset='ocolong'
  ),
  type='chain', parent="LE",
  label='StopLossLong',
  enabled=FALSE
)
```

- Belongs to orderset `ocolong`
- Rule type is `'chain'` and parent is 'LE'

Enable stoploss rule

```
rm.strat("multi.macd.stop") # remove portfolio, account, orderbook if re-run
```

```
initPortf(name="multi.macd.stop", symbols, initDate=initDate)
initAcct(name="multi.macd.stop", portfolios="multi.macd.stop",
  initDate=initDate, initEq=initEq)
initOrders(portfolio="multi.macd.stop", initDate=initDate)
```

```
enable.rule("macd",type="chain",labe="StopLoss")
```

```
out<-applyStrategy("macd" , portfolios="multi.macd.stop",
  parameters=list(nFast=fastMA, nSlow=slowMA, nSig=signalMA,maType=maType),
  verbose=TRUE)
```

```
updatePortf("multi.macd.stop")
updateAcct("multi.macd.stop")
updateEndEq("multi.macd.stop")
```

```
checkBlotterUpdate("multi.macd.stop","multi.macd.stop")

## [1] TRUE
```

Performance results with stoploss

```
equity.curve <- getAccount("multi.macd.stop")$summary$End.Eq
returns.sl <- Return.calculate(equity.curve,"log")
table.AnnualizedReturns(returns.sl,geometric = FALSE)
```

```
##                                End.Eq
## Annualized Return              0.0210
## Annualized Std Dev             0.0281
## Annualized Sharpe (Rf=0%) 0.7473
```

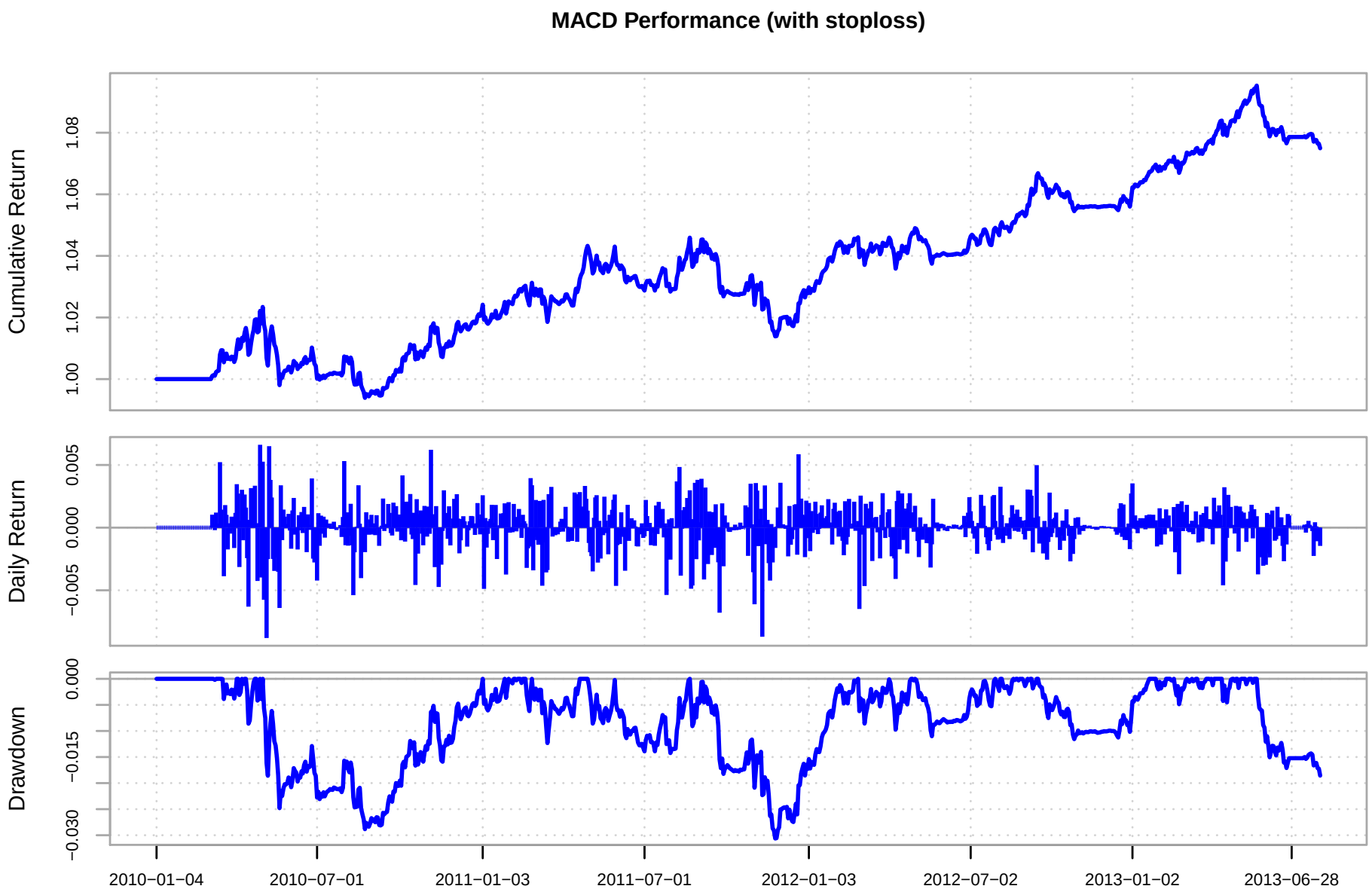
```
charts.PerformanceSummary(returns.sl,wealth.index=TRUE,geometric = FALSE,
  colorset="blue",xlab="",main="MACD Performance (with stoploss)",minor.ticks=FALSE
```

```
PerformanceAnalytics:::textplot(t(tradeStats("multi.macd.stop")))
```

```
chart.ME("multi.macd.stop",'VNQ',type='MAE',scale='percent')
```

```
ob <- getOrderBook("multi.macd.stop")$multi.macd.stop$VNQ
ob.df <- data.frame(Date=time(ob),coredata(ob),stringsAsFactors=FALSE)
ob.df$Order.Price <- round(as.numeric(ob.df$Order.Price),3)
PerformanceAnalytics:::textplot(ob.df,show.rownames=F)
```

MACD performance with stoploss



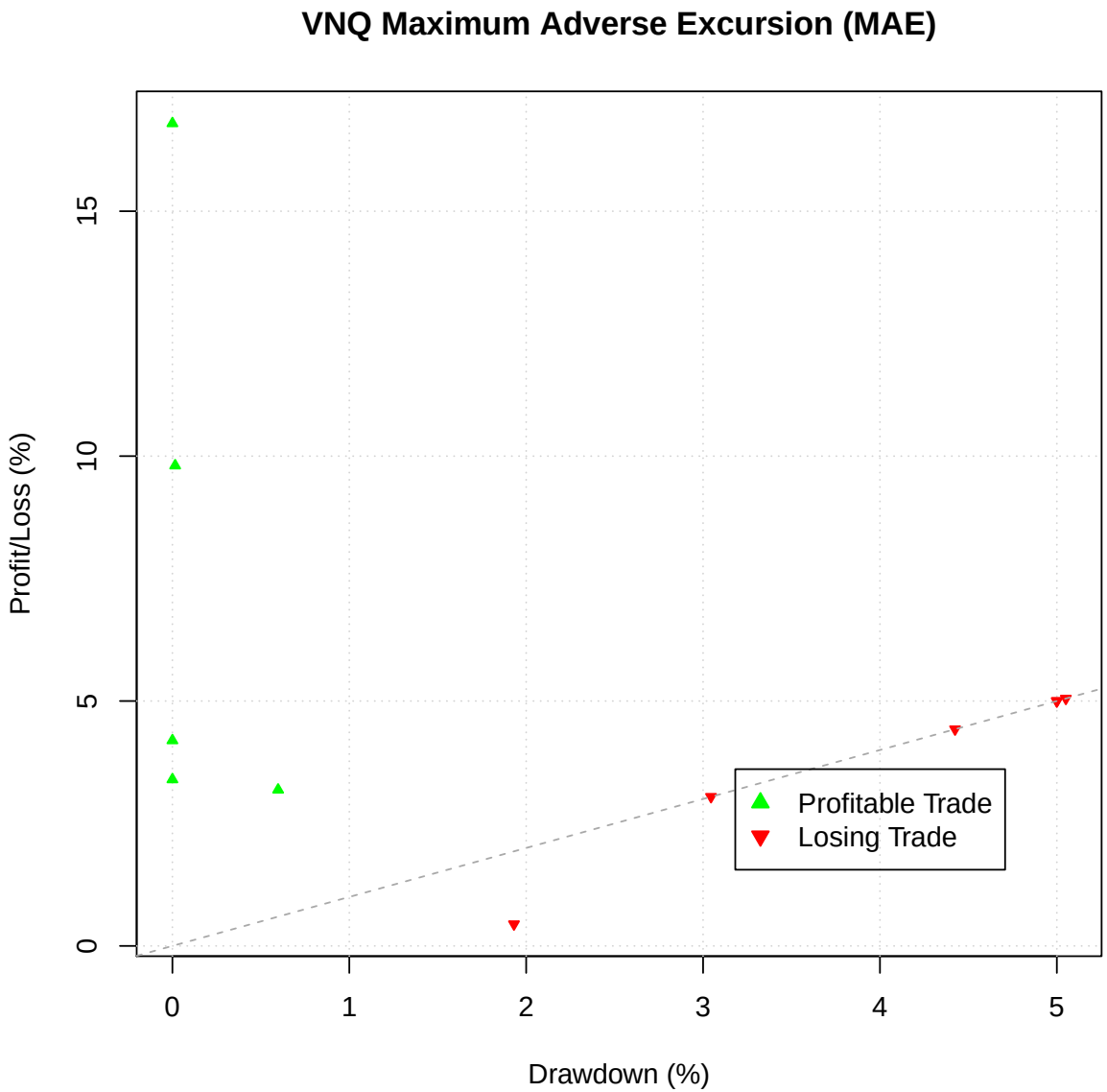
Trade stats for MACD strategy with stoploss

	AGG	GLD	ITOT	VNQ
Portfolio	multi.macd.stop	multi.macd.stop	multi.macd.stop	multi.macd.stop
Symbol	AGG	GLD	ITOT	VNQ
Num.Txns	16	18	21	21
Num.Trades	8	9	10	10
Net.Trading.PL	12082.766	19627.613	31866.836	14257.593
Avg.Trade.PL	1510.3458	2180.8459	3132.0836	1875.1593
Med.Trade.PL	187.68348	2492.00000	347.01546	1381.33074
Largest.Winner	6023.5203	10664.0000	17445.4703	16360.1052
Largest.Loser	−1019.4467	−5616.0000	−5088.1645	−5086.2237
Gross.Profits	13375.593	33139.013	50089.739	37223.230
Gross.Losses	−1292.8272	−13511.4000	−18768.9026	−18471.6369
Std.Dev.Trade.PL	2599.5428	5872.5837	8514.4779	7110.0840
Percent.Positive	62.500000	66.666667	50.000000	50.000000
Percent.Negative	37.500000	33.333333	50.000000	50.000000
Profit.Factor	10.3460022	2.4526706	2.6687623	2.0151560
Avg.Win.Trade	2675.1187	5523.1688	10017.9478	7444.6459
Med.Win.Trade	2122.1957	5821.5030	11648.5551	4318.7416
Avg.Losing.Trade	−430.94241	−4503.80000	−3753.78052	−3694.32738
Med.Losing.Trade	−250.04185	−5249.40000	−3791.74331	−4959.82655
Avg.Daily.PL	1510.3458	2180.8459	3132.0836	1875.1593
Med.Daily.PL	187.68348	2492.00000	347.01546	1381.33074
Std.Dev.Daily.PL	2599.5428	5872.5837	8514.4779	7110.0840
Ann.Sharpe	9.2231587	5.8951659	5.8394991	4.1866215
Max.Drawdown	−2921.0877	−29934.4000	−16471.8712	−29457.3861
Profit.To.Max.Draw	4.13639279	0.65568754	1.93462151	0.48400740
Avg.WinLoss.Ratio	6.2076013	1.2263353	2.6687623	2.0151560
Med.WinLoss.Ratio	8.48736199	1.10898446	3.07208429	0.87074448
Max.Equity	13078.139	42398.007	35973.569	32286.153
Min.Equity	−168.98432	−3996.00000	−9551.36238	−11779.18377
End.Equity	12082.766	19627.613	31866.836	14257.593

Order book for VNQ with stoploss

	Order.Qty	Order.Price	Order.Type	Order.Side	Order.Threshold	Order.Status	Order.StatusTime	Prefer	Order.Set	Txn.Fees	Rule	Time.In.Force
2010−03−04 00:00:00	2500	39.816	market	long		closed	2010−03−05 00:00:00		ocolong	0	LE	
2010−03−05 00:00:00	all	38.855	stoplimit	long	−2.04500908438919	replaced	2010−05−24		ocolong	0	StopLossLong	
2010−05−24 00:00:00	all	41.953	market	long		closed	2010−05−25 00:00:00		ocolong	0	LX	
2010−06−23 00:00:00	2300	43.897	market	long		closed	2010−06−24 00:00:00		ocolong	0	LE	
2010−06−24 00:00:00	all	40.819	stoplimit	long	−2.14838290307716	replaced	2010−06−29		ocolong	0	StopLossLong	
2010−06−29 00:00:00	all	42.107	market	long		closed	2010−06−30 00:00:00		ocolong	0	LX	
2010−07−27 00:00:00	2200	45.862	market	long		closed	2010−07−28 00:00:00		ocolong	0	LE	
2010−07−28 00:00:00	all	43.484	stoplimit	long	−2.28862145337188	closed	2010−08−24 00:00:00		ocolong	0	StopLossLong	
2010−12−27 00:00:00	2000	50.273	market	long		closed	2010−12−28 00:00:00		ocolong	0	LE	
2010−12−28 00:00:00	all	47.951	stoplimit	long	−2.52372390081176	replaced	2011−03−23		ocolong	0	StopLossLong	
2011−03−23 00:00:00	all	51.864	market	long		closed	2011−03−24 00:00:00		ocolong	0	LX	
2011−04−01 00:00:00	1900	53.917	market	long		closed	2011−04−04 00:00:00		ocolong	0	LE	
2011−04−04 00:00:00	all	51.186	stoplimit	long	−2.69402347989991	replaced	2011−06−14		ocolong	0	StopLossLong	
2011−06−14 00:00:00	all	54.516	market	long		closed	2011−06−15 00:00:00		ocolong	0	LX	
2011−07−06 00:00:00	1700	57.627	market	long		closed	2011−07−07 00:00:00		ocolong	0	LE	
2011−07−07 00:00:00	all	55.433	stoplimit	long	−2.91754502732244	closed	2011−08−01 00:00:00		ocolong	0	StopLossLong	
2011−10−27 00:00:00	1800	55.017	market	long		closed	2011−10−28 00:00:00		ocolong	0	LE	
2011−10−28 00:00:00	all	52.373	stoplimit	long	−2.75648405334092	closed	2011−11−09 00:00:00		ocolong	0	StopLossLong	
2011−12−12 00:00:00	1900	51.886	market	long		closed	2011−12−13 00:00:00		ocolong	0	LE	
2011−12−13 00:00:00	all	48.712	stoplimit	long	−2.56381144349004	replaced	2012−05−24		ocolong	0	StopLossLong	
2012−05−24 00:00:00	all	60.126	market	long		closed	2012−05−25 00:00:00		ocolong	0	LX	
2012−06−25 00:00:00	1700	60.361	market	long		closed	2012−06−26 00:00:00		ocolong	0	LE	
2012−06−26 00:00:00	all	57.535	stoplimit	long	−3.02817247468729	replaced	2012−10−01		ocolong	0	StopLossLong	
2012−10−01 00:00:00	all	62.628	market	long		closed	2012−10−02 00:00:00		ocolong	0	LX	
2012−12−12 00:00:00	1600	63.279	market	long		closed	2012−12−13 00:00:00		ocolong	0	LE	
2012−12−13 00:00:00	all	59.653	stoplimit	long	−3.13965624080501	replaced	2013−06−04		ocolong	0	StopLossLong	
2013−06−04 00:00:00	all	69.525	market	long		closed	2013−06−05 00:00:00		ocolong	0	LX	
2013−07−19 00:00:00	1400	72.330	market	long		closed	2013−07−22 00:00:00		ocolong	0	LE	
2013−07−22 00:00:00	all	68.922	stoplimit	long	−3.6275	open			ocolong	0	StopLossLong	

Maximum adverse excursion for VNQ with stoploss



Outline

Long-only MACD momentum strategy

Buy rule:

- Buy long when the MACD signal crosses above 0

Exit rule:

- Sell when the MACD signal crosses below 0

Stop rule:

- Stop loss set at 0.05% below entry price
- Stop loss set at 0.07% below position high

Trailing stop loss

```
trailingStopPercent <- 0.07
```

```
add.rule("macd", name = 'ruleSignal',
  arguments=list(sigcol="signal.gt.zero" , sigval=TRUE,
    replace=FALSE,
    orderside='long',
    ordertype='stoptrailing',
    tmult=TRUE,
    threshold=quote(trailingStopPercent),
    orderqty='all',
    orderset='ocolong'
  ),
  type='chain', parent="LE",
  label='StopTrailingLong',
  enabled=FALSE
)
```

- Belongs to orderset `ocolong`
- Rule type is `'chain'` and parent is 'LE'

Enable trailing stop rule

```
rm.strat("multi.macd.trail") # remove portfolio, account, orderbook if re-run
```

```
initPortf(name="multi.macd.trail", symbols, initDate=initDate)
initAcct(name="multi.macd.trail", portfolios="multi.macd.trail",
  initDate=initDate, initEq=initEq)
initOrders(portfolio="multi.macd.trail", initDate=initDate)
```

```
enable.rule("macd",type="chain",labe="StopTrailingLong")
```

```
out<-applyStrategy("macd" , portfolios="multi.macd.trail",
  parameters=list(nFast=fastMA, nSlow=slowMA, nSig=signalMA,maType=maType),
  verbose=TRUE)
```

```
updatePortf("multi.macd.trail")
updateAcct("multi.macd.trail")
updateEndEq("multi.macd.trail")
```

```
checkBlotterUpdate("multi.macd.trail","multi.macd.trail")

## [1] TRUE
```

Performance results with stoploss and trailing stop

```
equity.curve <- getAccount("multi.macd.trail")$summary$End.Eq
returns.tr <- Return.calculate(equity.curve,"log")
table.AnnualizedReturns(returns.tr,geometric = FALSE)
```

```
##                                End.Eq
## Annualized Return              0.0254
## Annualized Std Dev             0.0255
## Annualized Sharpe (Rf=0%) 0.9976
```

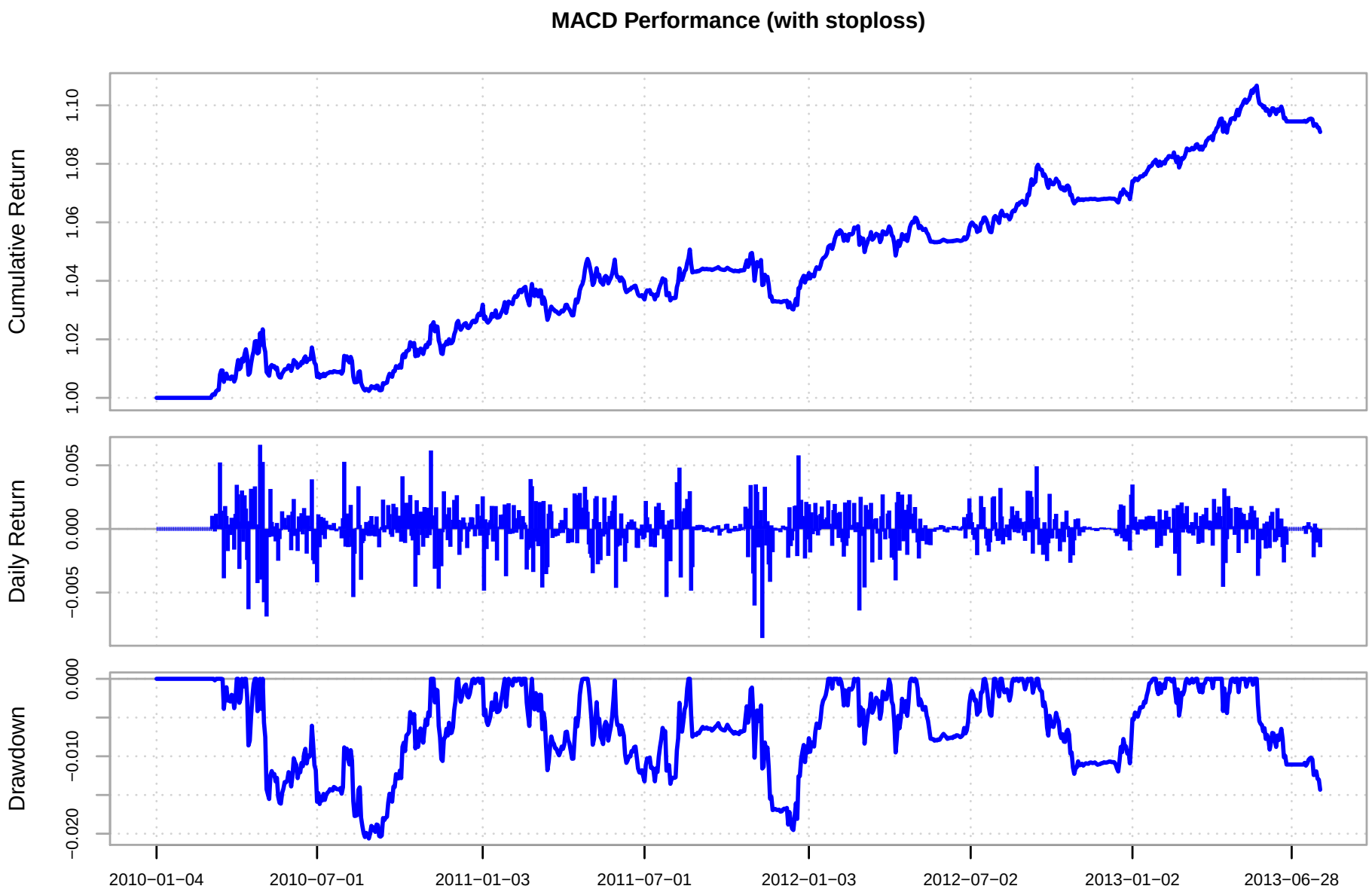
```
charts.PerformanceSummary(returns.tr,wealth.index=TRUE,geometric = FALSE,
  colorset="blue",xlab="",main="MACD Performance (with stoploss)",minor.ticks=FALSE
```

```
PerformanceAnalytics:::textplot(t(tradeStats("multi.macd.trail")))
```

```
chart.ME("multi.macd.trail",'VNQ',type='MAE',scale='percent')
```

```
ob <- getOrderBook("multi.macd.trail")$multi.macd.trail$VNQ
ob <- ob[ob$Order.Status=="closed",]
ob.df <- data.frame(Date=time(ob),coredata(ob),stringsAsFactors=FALSE)
ob.df$Order.Price <- round(as.numeric(ob.df$Order.Price),3)
PerformanceAnalytics:::textplot(ob.df,show.rownames=F)
```

MACD performance with stoploss and trailing stop



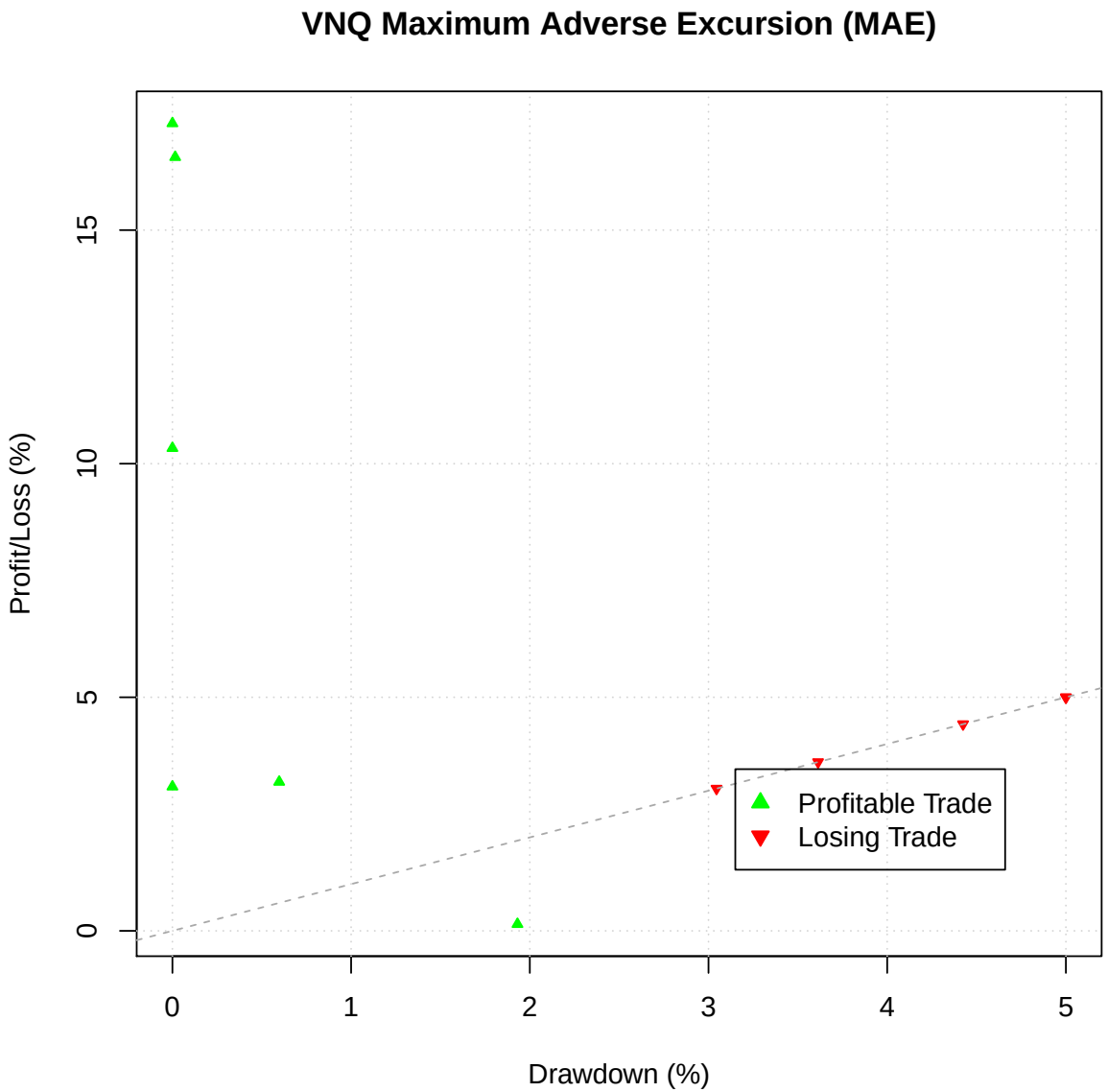
Trade stats with stoploss and trailing stop

	AGG	GLD	ITOT	VNQ
Portfolio	multi.macd.trail	multi.macd.trail	multi.macd.trail	multi.macd.trail
Symbol	AGG	GLD	ITOT	VNQ
Num.Txns	16	18	21	21
Num.Trades	8	9	10	10
Net.Trading.PL	12082.766	31058.760	22475.376	29521.072
Avg.Trade.PL	1510.3458	3450.9733	2192.9376	3401.5072
Med.Trade.PL	187.68348	5085.00000	−1221.65989	1661.71453
Largest.Winner	6023.5203	13923.1470	13958.6017	16839.1614
Largest.Loser	−1019.4467	−5616.0000	−5088.1645	−4961.6713
Gross.Profits	13375.593	44570.160	41624.551	50584.074
Gross.Losses	−1292.8272	−13511.4000	−19695.1750	−16569.0023
Std.Dev.Trade.PL	2599.5428	7063.6722	7689.6761	8487.2990
Percent.Positive	62.500000	66.666667	40.000000	60.000000
Percent.Negative	37.500000	33.333333	60.000000	40.000000
Profit.Factor	10.3460022	3.2987078	2.1134390	3.0529342
Avg.Win.Trade	2675.1187	7428.3600	10406.1377	8430.6791
Med.Win.Trade	2122.1957	7269.0065	12044.0550	6891.2761
Avg.Losing.Trade	−430.94241	−4503.80000	−3282.52916	−4142.25057
Med.Losing.Trade	−250.04185	−5249.40000	−3629.14529	−4299.12538
Avg.Daily.PL	1510.3458	3450.9733	2192.9376	3401.5072
Med.Daily.PL	187.68348	5085.00000	−1221.65989	1661.71453
Std.Dev.Daily.PL	2599.5428	7063.6722	7689.6761	8487.2990
Ann.Sharpe	9.2231587	7.7555274	4.5270834	6.3621245
Max.Drawdown	−2921.0877	−18503.2530	−19147.7247	−20318.4053
Profit.To.Max.Draw	4.1363928	1.6785567	1.1737883	1.4529227
Avg.WinLoss.Ratio	6.2076013	1.6493539	3.1701585	2.0352895
Med.WinLoss.Ratio	8.4873620	1.3847309	3.3187029	1.6029484
Max.Equity	13078.139	42398.007	28727.069	40762.630
Min.Equity	−168.98432	−3996.00000	−9581.18286	−2640.20303
End.Equity	12082.766	31058.760	22475.376	29521.072

Order book for VNQ with stoploss and trailing stop

	Order.Qty	Order.Price	Order.Type	Order.Side	Order.Threshold	Order.Status	Order.StatusTime	Prefer	Order.Set	Txn.Fees	Rule	Time.In.Force
2010−03−04 00:00:00	2500	39.816	market	long		closed	2010−03−05 00:00:00		ocolong	0	LE	
2010−04−29 00:00:00	all	45.126	stoptrailing	long	−2.86301271814487	closed	2010−05−06 00:00:00		ocolong	0	StopTrailingLong	
2010−06−23 00:00:00	2300	43.897	market	long		closed	2010−06−24 00:00:00		ocolong	0	LE	
2010−06−29 00:00:00	all	42.107	market	long		closed	2010−06−30 00:00:00		ocolong	0	LX	
2010−07−27 00:00:00	2200	45.862	market	long		closed	2010−07−28 00:00:00		ocolong	0	LE	
2010−08−02 00:00:00	all	44.119	stoptrailing	long	−3.20407003472063	closed	2010−08−23 00:00:00		ocolong	0	StopTrailingLong	
2010−12−27 00:00:00	2000	50.273	market	long		closed	2010−12−28 00:00:00		ocolong	0	LE	
2011−03−23 00:00:00	all	51.864	market	long		closed	2011−03−24 00:00:00		ocolong	0	LX	
2011−04−01 00:00:00	1900	53.917	market	long		closed	2011−04−04 00:00:00		ocolong	0	LE	
2011−05−31 00:00:00	all	53.957	stoptrailing	long	−3.77163287185988	closed	2011−06−10 00:00:00		ocolong	0	StopTrailingLong	
2011−07−06 00:00:00	1700	57.627	market	long		closed	2011−07−07 00:00:00		ocolong	0	LE	
2011−07−07 00:00:00	all	55.433	stoplimit	long	−2.91754502732244	closed	2011−08−01 00:00:00		ocolong	0	StopLossLong	
2011−10−27 00:00:00	1800	55.017	market	long		closed	2011−10−28 00:00:00		ocolong	0	LE	
2011−10−28 00:00:00	all	52.373	stoplimit	long	−2.75648405334092	closed	2011−11−09 00:00:00		ocolong	0	StopLossLong	
2011−12−12 00:00:00	1900	51.886	market	long		closed	2011−12−13 00:00:00		ocolong	0	LE	
2012−05−01 00:00:00	all	60.139	stoptrailing	long	−3.58933602088606	closed	2012−05−17 00:00:00		ocolong	0	StopTrailingLong	
2012−06−25 00:00:00	1700	60.361	market	long		closed	2012−06−26 00:00:00		ocolong	0	LE	
2012−09−14 00:00:00	all	62.432	stoptrailing	long	−4.2394414645622	closed	2012−10−01 00:00:00		ocolong	0	StopTrailingLong	
2012−12−12 00:00:00	1600	63.279	market	long		closed	2012−12−13 00:00:00		ocolong	0	LE	
2013−05−21 00:00:00	all	73.192	stoptrailing	long	−4.39551873712702	closed	2013−05−29 00:00:00		ocolong	0	StopTrailingLong	
2013−07−19 00:00:00	1400	72.330	market	long		closed	2013−07−22 00:00:00		ocolong	0	LE	

MAE for VNQ with stoploss and trailing stop



Outline

Parallel computing with foreach

- The foreach package facilitates easily-accessible parallel processing in R
- The foreach function is a for-like looping construct where each iteration of the for loop can be run in parallel if a multicore processor (now very common) is available
- Each loop iteration returns a result and these results can be combined in a variety of ways depending on their data type
- foreach requires that you register a *parallel backend*
  - On Windows platforms, doParallel is the recommend parallel backend
  - On Linux/Mac platforms, doMC is the recommend parallel backend
  - doSNOW is a parallel backend that can run on both Windows and Linux

Setup parallel backend and test foreach

```
library(parallel)
detectCores()

## [1] 8
```

```
if( Sys.info()['sysname'] == "Windows" )
{
  library(doParallel)
  registerDoParallel(cores=detectCores())
} else {
  library(doMC)
  registerDoMC(cores=detectCores())
}
```

```
foreach(i=1:8, .combine=c) %dopar% sqrt(i)

## [1] 1.0000000 1.4142136 1.7320508 2.0000000 2.2360680 2.4494897 2.6457513
## [8] 2.8284271
```

- All sqrt operations are run in parallel via separate processes on a multi-core processor

Remove parallel backend on Windows

```
if( Sys.info()['sysname'] == "Windows" )
{
  registerDoSEQ()
}
```

Optimization in quantstrat

Optimization in quantstrat is implemented using a concept call a paramset; along with paramsets, there are distributions and constraints.

paramset A paramset is a collection of variables that will be optimized subject to their range of allowed values (distribution) and any constraints between them

distribution A distribution in a paramset is simply the range of values that a variable is allowed to take (e.g. fastMA $=$ 1:20)

constraint A constraint is a relationship that must be true between two distributions in a paramset (e.g. fastMA $<$ slowMA)

Optimization functions in quantstrat

The following functions implement parameter optimization in quantstrat:

add.distribution	Creates a distribution in paramset, where a distribution consists of the name of a variable in a strategy component plus a range of values for this variable.
add.distribution.constraint	Creates a constraint on 2 distributions in a paramset, i.e. a restriction limiting the allowed combinations from the ranges for distribution 1 and distribution 2.
apply.paramset	Runs `applyStrategy` once for each parameter combination as specified by the parameter distributions and constraints in the paramset. `apply.paramset` will do parallel processing on multiple cores if available.

Optimization range for stop loss

```
args(add.distribution)

## function (strategy, paramset.label, component.type, component.label,
##     variable, weight = NULL, label, store = TRUE)
## NULL
```

```
stopLossPercentRange <- seq(0.03,0.05,by=0.01)
```

```
add.distribution("macd",
  paramset.label = "STOPOPT",
  component.type = "chain",
  component.label = "StopLossLong",
  variable = list( threshold = stopLossPercentRange ),
  label = "StopLossLONG"
)
```

Optimization range for stop loss

```
trailingPercentRange <- seq(0.03,0.05,by=0.01)
```

```
add.distribution("macd",
  paramset.label = "STOPOPT",
  component.type = "chain",
  component.label = "StopTrailingLong",
  variable = list( threshold = trailingPercentRange ),
  label = "TrailingLONG"
)
```

Initialize portfolio, account, and orders

```
rm.strat("multi.macd.opt") # remove portfolio, account, orderbook if re-run
```

```
initPortf(name="multi.macd.opt", symbols, initDate=initDate)
initAcct(name="multi.macd.opt", portfolios="multi.macd.opt",
  initDate=initDate, initEq=initEq)
initOrders(portfolio="multi.macd.opt", initDate=initDate)
```

The apply.paramset function

The function apply.paramset function will run applyStrategy() on portfolio.st, once for each parameter combination as specified by the parameter distributions and constraints in the paramset

```
args(apply.paramset)

## function (strategy.st, paramset.label, portfolio.st, account.st,
##     mktdata = NULL, nsamples = 0, user.func = NULL, user.args = NULL,
##     calc = "slave", audit = NULL, packages = NULL, verbose = FALSE,
##     paramsets, ...)
## NULL
```

Main arguments:

strategy.st	text name of the strategy
paramset.label	text name of the paramset
portfolio.st	text name of the portfolio
nsamples	if nsamples $>$ 0 then take a sample of size nsamples from the paramset

Apply strategy and verify

```
if( Sys.info()['sysname'] == "Windows" )
{
  library(doParallel)
#  registerDoParallel(cores=detectCores())
} else {
  library(doMC)
  registerDoMC(cores=detectCores())
}
```

```
if( file.exists("resultsStopOpt.RData") )
{
  load("resultsStopOpt.RData")
} else {
  results <- apply.paramset("macd", paramset.label = "STOPOPT",
    portfolio="multi.macd.opt", account="multi.macd.opt", nsamples=0)
  save(list="results",file="resultsStopOpt.RData")
}
```

As of 2015-04-30, apply.paramset does not appear to run properly in parallel on Windows. To run on a Windows platform, load the doParallel package but do not call the registerDoParallel function; apply.paramset will then be able to run in sequential rather than parallel mode.

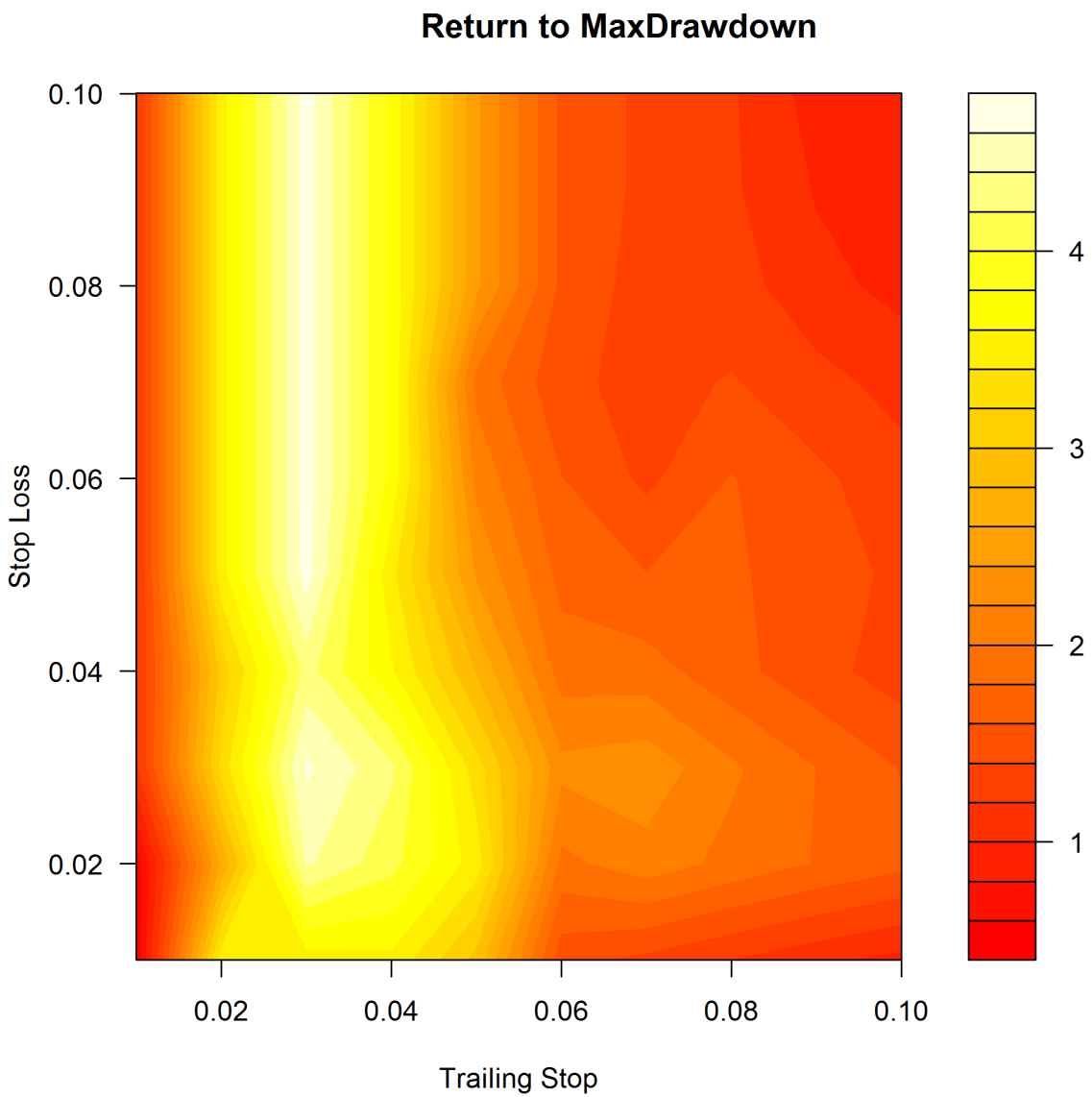
Results returns from apply.paramset

```
head(names(results),20)

##  [1] "multi.macd.opt.1"  "tradeStats"        "multi.macd.opt.2"
##  [4] "multi.macd.opt.3"  "multi.macd.opt.4"  "multi.macd.opt.5"
##  [7] "multi.macd.opt.6"  "multi.macd.opt.7"  "multi.macd.opt.8"
## [10] "multi.macd.opt.9"  "multi.macd.opt.10" "multi.macd.opt.11"
## [13] "multi.macd.opt.12" "multi.macd.opt.13" "multi.macd.opt.14"
## [16] "multi.macd.opt.15" "multi.macd.opt.16" "multi.macd.opt.17"
## [19] "multi.macd.opt.18" "multi.macd.opt.19"
```

Heatmaps of strategy performance

```
z <- tapply(X=results$tradeStats$Profit.To.Max.Draw,
  INDEX=list(results$tradeStats$TrailingLONG,results$tradeStats$StopLossLONG),
  FUN=median)
x <- as.numeric(rownames(z))
y <- as.numeric(colnames(z))

filled.contour(x=x,y=y,z=z,color = heat.colors,
  xlab="Trailing Stop",ylab="Stop Loss")
title("Return to MaxDrawdown")
```

Return to maximum drawdown



Outline

Define indicators and signals

```
strategy("macd.opt", store=TRUE)
```

```
add.indicator("macd.opt", name = "MACD",
  arguments = list(x=quote(Cl(mktdata))),label='osc')
```

```
add.signal("macd.opt",name="sigThreshold",
  arguments=list(column="signal.osc",relationship="gt",threshold=0,cross=TRUE),
  label="signal.gt.zero")
```

```
add.signal("macd.opt",name="sigThreshold",
  arguments=list(column="signal.osc",relationship="lt",threshold=0,cross=TRUE),
  label="signal.lt.zero")
```

Long entry/exit rule

```
add.rule("macd.opt",name='ruleSignal',
  arguments = list(sigcol="signal.gt.zero", sigval=TRUE,
    replace=FALSE,
    orderside='long',
    ordertype='market',
    orderqty=100,
    osFUN='osFixedDollar',
    orderset='ocolong'
  ),
  type='enter',
  label='LE'
)

add.rule("macd.opt",name='ruleSignal',
  arguments = list(sigcol="signal.lt.zero", sigval=TRUE,
    replace=TRUE,
    orderside='long',
    ordertype='market',
    orderqty='all',
    orderset='ocolong'
  ),
  type='exit',
  label='LX'
)
```

Long stop loss

```
stopLossPercent <- 0.03
```

```
add.rule("macd.opt",name='ruleSignal',
  arguments = list(sigcol="signal.gt.zero", sigval=TRUE,
    replace=FALSE,
    orderside='long',
    ordertype='stoplimit',
    tmult=TRUE,
    threshold=quote( stopLossPercent ),
    orderqty='all',
    orderset='ocolong'
  ),
  type='chain', parent="LE",
  label='StopLossLong',
  enabled=TRUE
)
```

Trailing stop loss

```
trailingStopPercent <- 0.03
```

```
add.rule("macd.opt", name = 'ruleSignal',
  arguments=list(sigcol="signal.gt.zero" , sigval=TRUE,
    replace=FALSE,
    orderside='long',
    ordertype='stoptrailing',
    tmult=TRUE,
    threshold=quote(trailingStopPercent),
    orderqty='all',
    orderset='ocolong'
  ),
  type='chain', parent="LE",
  label='StopTrailingLong',
  enabled=TRUE
)
```

Apply optimal settings

```
rm.strat("multi.macd.opt") # remove portfolio, account, orderbook if re-run
```

```
initPortf(name="multi.macd.opt", symbols, initDate=initDate)
initAcct(name="multi.macd.opt", portfolios="multi.macd.opt",
  initDate=initDate, initEq=initEq)
initOrders(portfolio="multi.macd.opt", initDate=initDate)
```

```
out<-applyStrategy("macd.opt" , portfolios="multi.macd.opt",
  parameters=list(nFast=fastMA, nSlow=slowMA, nSig=signalMA,maType=maType),
  verbose=TRUE)
```

```
updatePortf("multi.macd.opt")
updateAcct("multi.macd.opt")
updateEndEq("multi.macd.opt")
```

```
checkBlotterUpdate("multi.macd.opt","multi.macd.opt")

## [1] TRUE
```

Performance results with optimal settings

```
equity.curve <- getAccount("multi.macd.opt")$summary$End.Eq
returns.opt <- Return.calculate(equity.curve,"log")
table.AnnualizedReturns(returns.opt,geometric = FALSE)
```

```
##                             End.Eq
## Annualized Return           0.0268
## Annualized Std Dev          0.0143
## Annualized Sharpe (Rf=0%) 1.8727
```

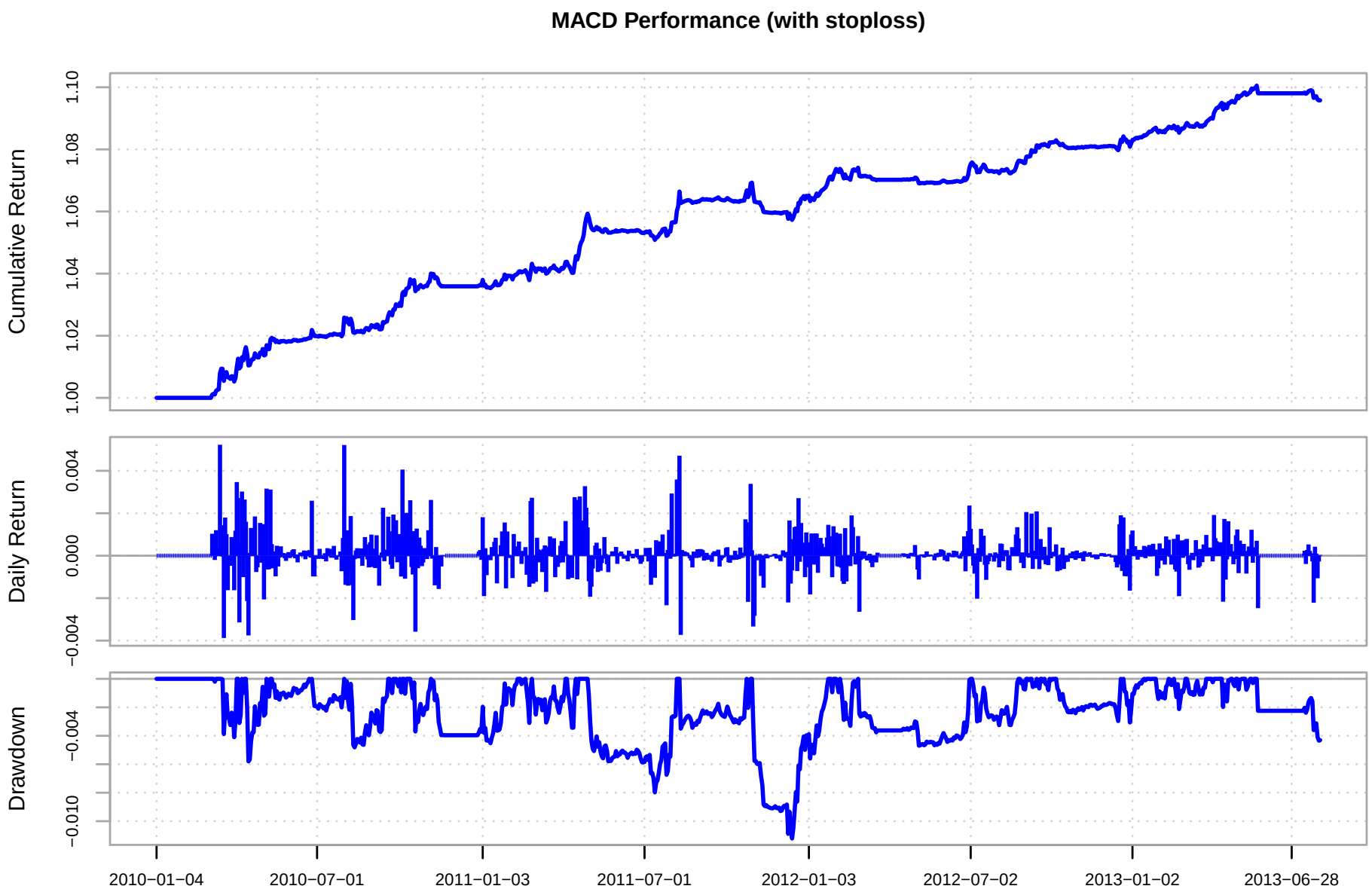
```
charts.PerformanceSummary(returns.opt,wealth.index=TRUE,geometric = FALSE,
  colorset="blue",xlab="",main="MACD Performance (with stoploss)",minor.ticks=FALSE
```

```
PerformanceAnalytics:::textplot(t(tradeStats("multi.macd.opt")))
```

```
chart.ME("multi.macd.opt",'VNQ',type='MAE',scale='percent')
```

```
ob <- getOrderBook("multi.macd.opt")$multi.macd.opt$VNQ
ob <- ob[ob$Order.Status=="closed",]
ob.df <- data.frame(Date=time(ob),coredata(ob),stringsAsFactors=FALSE)
ob.df$Order.Price <- round(as.numeric(ob.df$Order.Price),3)
PerformanceAnalytics:::textplot(ob.df,show.rownames=F)
```

MACD performance with optimal settings



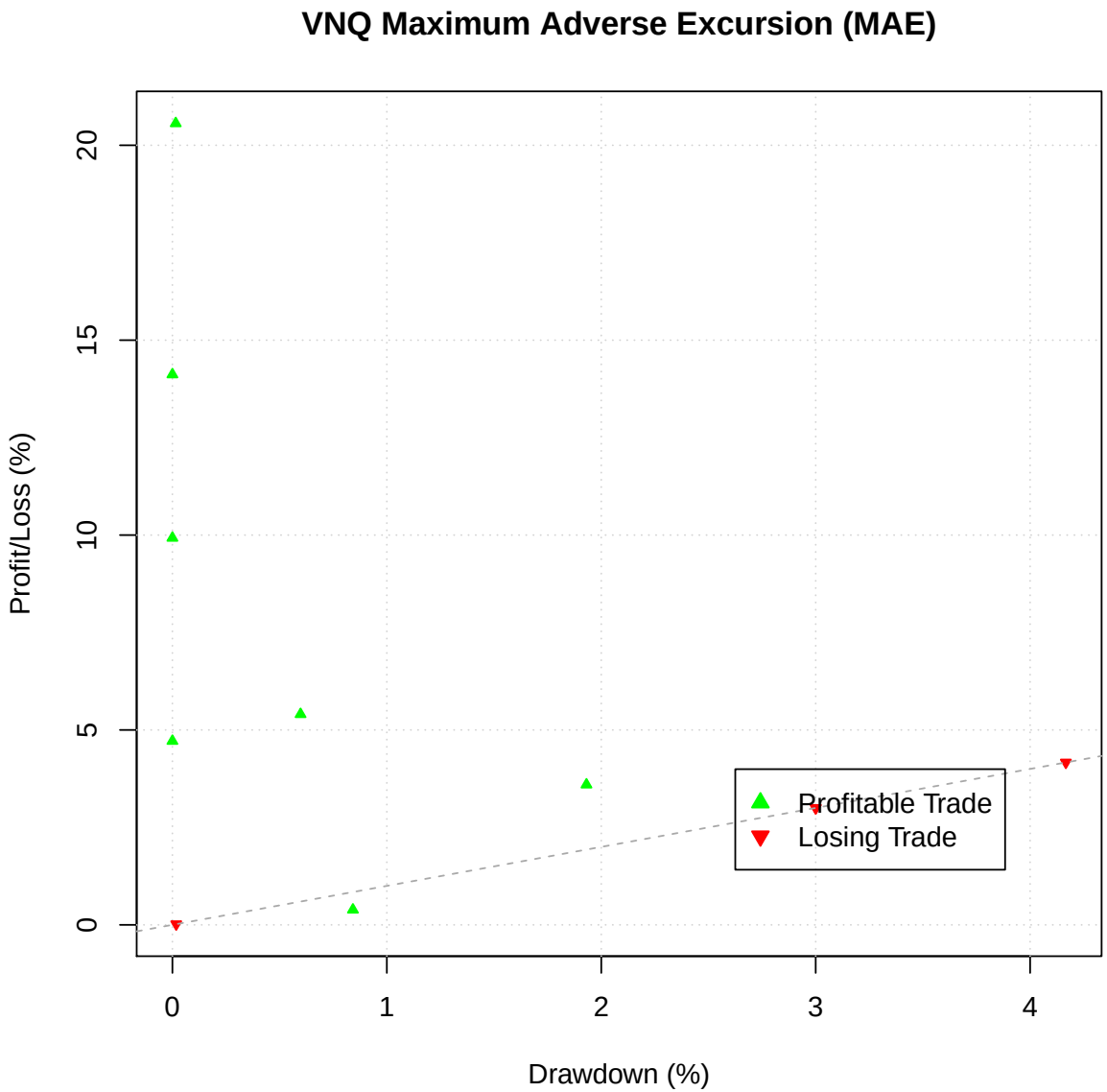
Trade stats with optimal settings

	AGG	GLD	ITOT	VNQ
Portfolio	multi.macd.opt	multi.macd.opt	multi.macd.opt	multi.macd.opt
Symbol	AGG	GLD	ITOT	VNQ
Num.Txns	16	18	21	22
Num.Trades	8	9	10	11
Net.Trading.PL	12082.7662	36490.4012	3182.5269	48767.3033
Avg.Trade.PL	1510.34578	4054.48902	263.65269	4433.39121
Med.Trade.PL	187.68348	5589.45000	−791.99440	3681.36559
Largest.Winner	6023.5203	11456.0600	6475.4303	20657.6916
Largest.Loser	−1019.4467	−3149.6400	−3102.8443	−4134.7261
Gross.Profits	13375.593	42625.941	14067.171	58942.544
Gross.Losses	−1292.8272	−6135.5400	−11430.6436	−10175.2406
Std.Dev.Trade.PL	2599.5428	5541.5201	3259.4109	7778.2643
Percent.Positive	62.500000	66.666667	30.000000	63.636364
Percent.Negative	37.500000	33.333333	70.000000	36.363636
Profit.Factor	10.3460022	6.9473822	1.2306543	5.7927420
Avg.Win.Trade	2675.1187	7104.3235	4689.0569	8420.3634
Med.Win.Trade	2122.1957	8270.8916	3867.6101	5454.0224
Avg.Losing.Trade	−430.94241	−2045.18000	−1632.94909	−2543.81016
Med.Losing.Trade	−250.04185	−2962.44000	−1595.25278	−3011.49796
Avg.Daily.PL	1510.34578	4054.48902	263.65269	4433.39121
Med.Daily.PL	187.68348	5589.45000	−791.99440	3681.36559
Std.Dev.Daily.PL	2599.5428	5541.5201	3259.4109	7778.2643
Ann.Sharpe	9.2231587	11.6146863	1.2840838	9.0480217
Max.Drawdown	−2921.0877	−7111.5800	−12000.2540	−9849.4293
Profit.To.Max.Draw	4.13639279	5.13112434	0.26520496	4.95128215
Avg.WinLoss.Ratio	6.2076013	3.4736911	2.8715267	3.3101383
Med.WinLoss.Ratio	8.4873620	2.7919187	2.4244497	1.8110663
Max.Equity	13078.139	39006.915	14467.781	54543.202
Min.Equity	−168.98432	−4312.44000	0.00000	0.00000
End.Equity	12082.7662	36490.4012	3182.5269	48767.3033

Order book for VNQ with optimal settings

	Order.Qty	Order.Price	Order.Type	Order.Side	Order.Threshold	Order.Status	Order.StatusTime	Prefer	Order.Set	Txn.Fees	Rule	Time.In.Force
2010−03−04 00:00:00	2500	39.816	market	long		closed	2010−03−05 00:00:00		ocolong	0	LE	
2010−04−13 00:00:00	all	44.960	stoptrailing	long	−1.22700545063352	closed	2010−04−15 00:00:00		ocolong	0	StopTrailingLong	
2010−06−23 00:00:00	2300	43.897	market	long		closed	2010−06−24 00:00:00		ocolong	0	LE	
2010−06−25 00:00:00	all	42.960	stoptrailing	long	−1.2890297418463	closed	2010−06−29 00:00:00		ocolong	0	StopTrailingLong	
2010−07−27 00:00:00	2200	45.862	market	long		closed	2010−07−28 00:00:00		ocolong	0	LE	
2010−08−02 00:00:00	all	45.949	stoptrailing	long	−1.37317287202313	closed	2010−08−11 00:00:00		ocolong	0	StopTrailingLong	
2010−12−27 00:00:00	2000	50.273	market	long		closed	2010−12−28 00:00:00		ocolong	0	LE	
2011−02−28 00:00:00	all	53.201	stoptrailing	long	−1.51423434048705	closed	2011−03−01 00:00:00		ocolong	0	StopTrailingLong	
2011−04−01 00:00:00	1900	53.917	market	long		closed	2011−04−04 00:00:00		ocolong	0	LE	
2011−04−28 00:00:00	all	55.818	stoptrailing	long	−1.61641408793995	closed	2011−05−06 00:00:00		ocolong	0	StopTrailingLong	
2011−07−06 00:00:00	1700	57.627	market	long		closed	2011−07−07 00:00:00		ocolong	0	LE	
2011−07−07 00:00:00	all	56.600	stoplimit	long	−1.75052701639346	closed	2011−07−14 00:00:00		ocolong	0	StopLossLong	
2011−10−27 00:00:00	1800	55.017	market	long		closed	2011−10−28 00:00:00		ocolong	0	LE	
2011−10−28 00:00:00	all	53.476	stoplimit	long	−1.65389043200455	closed	2011−11−01 00:00:00		ocolong	0	StopLossLong	
2011−12−12 00:00:00	1900	51.886	market	long		closed	2011−12−13 00:00:00		ocolong	0	LE	
2012−02−03 00:00:00	all	58.516	stoptrailing	long	−1.53828686609403	closed	2012−02−15 00:00:00		ocolong	0	StopTrailingLong	
2012−06−25 00:00:00	1700	60.361	market	long		closed	2012−06−26 00:00:00		ocolong	0	LE	
2012−07−17 00:00:00	all	63.419	stoptrailing	long	−1.81690348481237	closed	2012−07−23 00:00:00		ocolong	0	StopTrailingLong	
2012−12−12 00:00:00	1600	63.279	market	long		closed	2012−12−13 00:00:00		ocolong	0	LE	
2013−05−21 00:00:00	all	75.704	stoptrailing	long	−1.88379374448301	closed	2013−05−22 00:00:00		ocolong	0	StopTrailingLong	
2013−07−19 00:00:00	1400	72.330	market	long		closed	2013−07−22 00:00:00		ocolong	0	LE	
2013−07−22 00:00:00	all	70.374	stoplimit	long	−2.1765	closed	2013−07−30 00:00:00		ocolong	0	StopLossLong	

MAE for VNQ with optimal settings

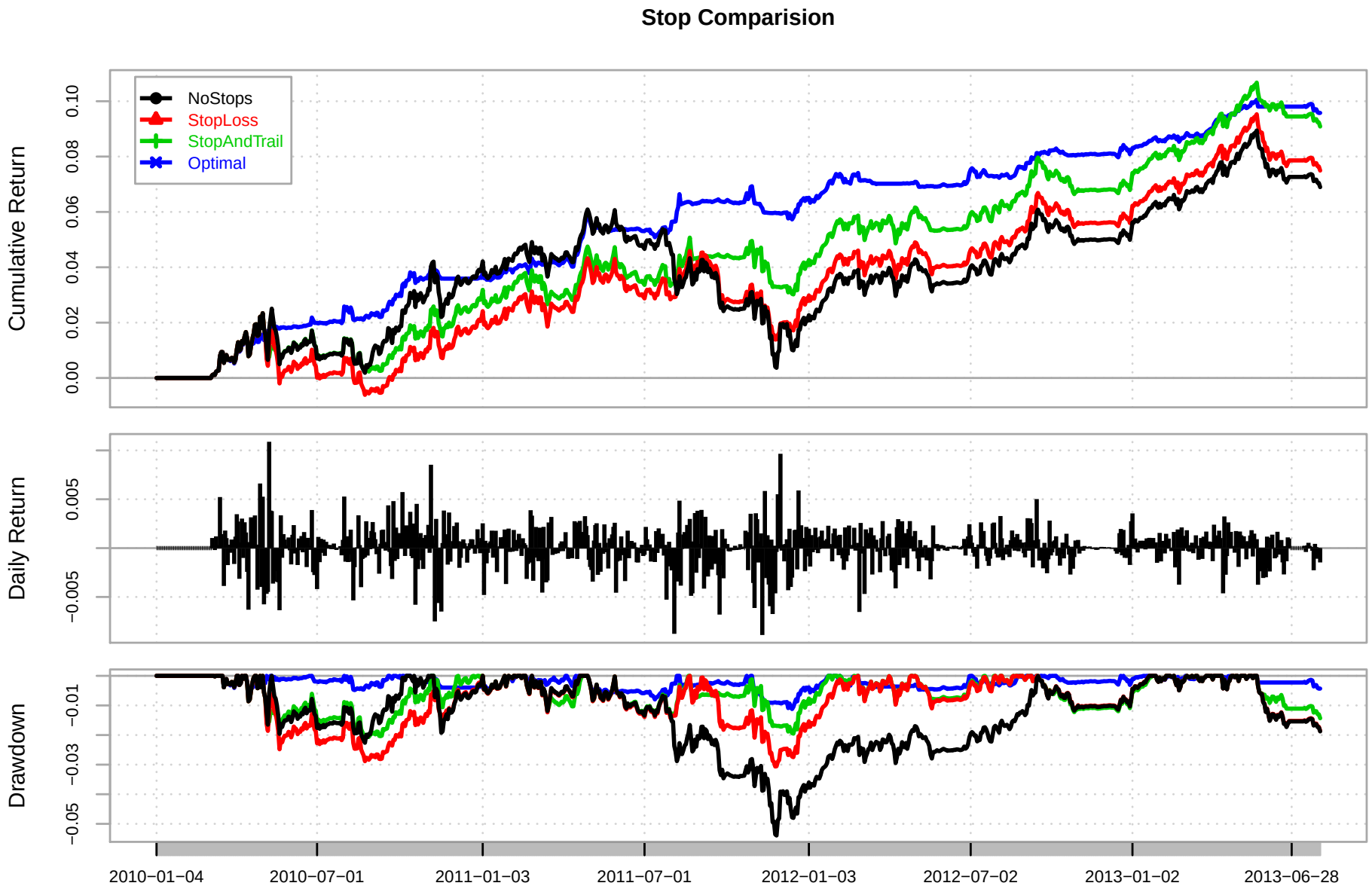


Comparison of stops

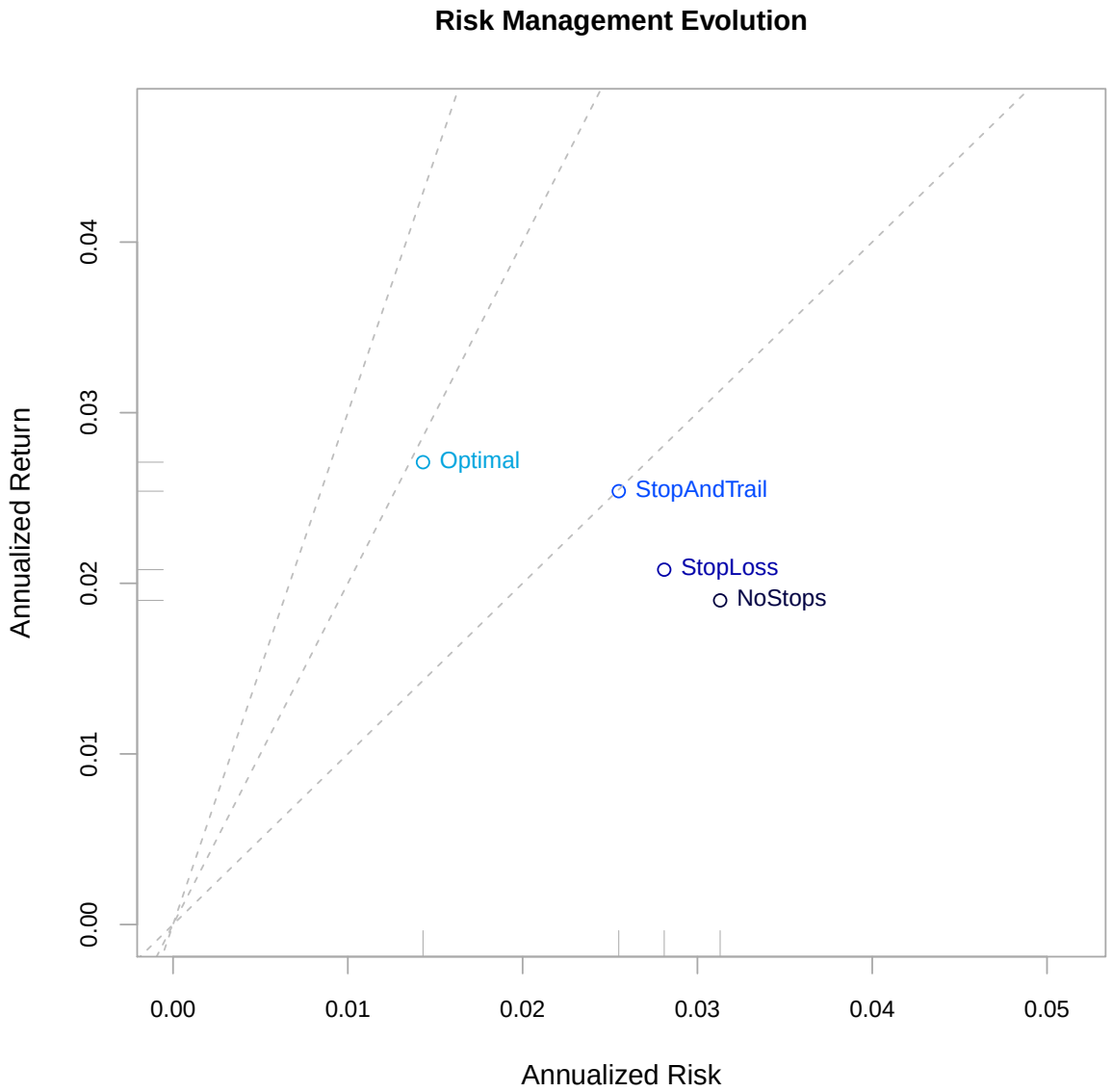
```
rets <- cbind(returns.ns,returns.sl,returns.tr,returns.opt)
colnames(rets) <- c("NoStops","StopLoss","StopAndTrail","Optimal")
charts.PerformanceSummary(rets,geometric = FALSE,main="Stop Comparision")
```

```
chart.RiskReturnScatter(rets,
main = "Risk Management Evolution", colorset = rich10equal)
```

Comparison of stops



Risk management progression



Outline

Wrap up

- No class on Tuesday May 5th
- Mid-term exam
  - Puget-Sound area students:
    - Thursday May 7, 2015 @ 1:30 PM PDT in Lowe 202
  - Out-of-state students:
    - Completed proctor form should be submitted now!
    - Verify you proctor and their email posted on Canvas
    - Schedule test for Thursday May 7, 2015 with your proctor
- Questions, comments, concerns
  - Post to the discussion forum on Canvas
  - Xin, chenx26@uw.edu
  - Guy, gyollin@uw.edu

COMPUTATIONAL FINANCE & RISK MANAGEMENT

UNIVERSITY *of* WASHINGTON

Department of Applied Mathematics

`http://depts.washington.edu/compfin`