Strategy Tester

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October 22, 2012

I'll demonstrate how the parts of the Strategy Tester works by apply it to a simple Moving Average momentum example. The code's a bit of overkill for this example, but I'll put comments in to explain the reason for the design along the way. At the end I'll talk about how structure should generalise to more complex examples like strategies on curves.

The R code is broken into a few files:

- *Main.R* executes our strategy. It imports data, constructs required object, and displays results. However, it doesn't have function definitions, it's just a list of commands we want to execute.
- *MarketDataClasses.R, TradeClasses.R, PortfolioClasses.R, TradeStrategyClasses.R* have code that defines the different object we want to create, i.e. classes, and things we want to do to them, i.e. class functions (aka member functions). These files don't execute commands, except for a couple to check the classes are working properly. They just define objects and how they interact.

In the example below I'll just go through the execution of *Main.R* to show how I see the logical parts fitting together.

If you want we can go through class definitions later, but seeing as though we are probably going to do coding in futuer in Python/C++ then probably not worth spending too much time on R implementation as R OO is a bit weird.

I've broken the discussion into a few sections, corresponding a quick description of the MA strategy and then logical sections of the *Main.R* code. The fist part of *Main.R* basically just imports data for the AllOrds index, adds MA's and formats in a way that can be used by the StrategyTester classes. The second part gives a description of how to build Trade objects and combine them into Portfolio objects, then price/value them against the data, with comments on resoning behind definitions. Part 3 describes creating a TradeStrategy object from a MarketData and a Portfolio object, and then operations you can do on the TradeStrategy object like run the strategy and look at the results - this is the main section for generating strategy results, which is done in only a few lines. Part 4 is just goes through the chunk of code to display the results. The last part is discussion of further things we can do.

1 Moving Average Momentum Example

The basic idea, illustrated in Figure 1 below, is to take two moving averages of a time series MA1, MA2 where MA1 had less lags than MA2. We think of MA2 as being a more long term average than MA1, and so when MA1 crosses MA2 there is momentum away from the longterm average, and we trade in that direction. I.e. trade when lines cross in the direction of green line crossing blue line: upcross and we put on a buy; downcross we put on a sell; otherwise we hold. Sounds a bit too simple to work - we can test results with StategyTester.

The code in the "Main.R" file runs through this for the AORD index from Yahoo finance using StrategyTester. The final results of portfolio value of strategy are in Figure 1. Note, I've assumed interest rates are zero, so when only cash position, we have no change in portfolio value. This is easy to change in future.

Figure 1: AORD index with MA's. Generated by quantmod

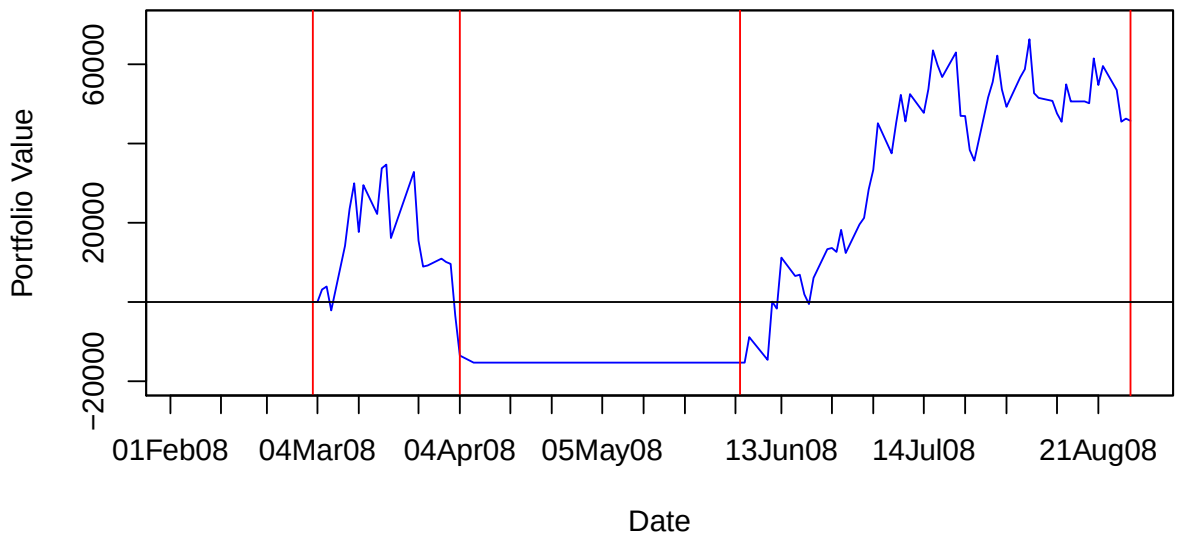


Figure 2: AORD index with MA's. Generated by quantmod

1.1 Data Import

The first portion of *Main.R* code doesn't have much to do with the StrategyTester files. It just uses R and quantmod to load in data and construct the moving averages.

First we load the libraries we need

```
library(xts)
library(zoo)
library(quantmod)
```

Then we set the working directory so that it will include the StrategyTester class files correctly,

```
setwd("~/Documents/R/StrategyTester")
```

Next we import data.

```
AORD = as.xts(as.zoo(read.table("Data/AORD.csv", header = T, sep = ",")))
```

The csv loaded here was one I prepared ealier using quantmod's canned functions for downloading yahoo data.

We then use quantmod to create the moving averages series by charting AORD then adding MAs, and extracting series values. I've supressed chart as it just Figure 1 above.

```
chartData = AORD["2008-02::2008-08"]
chartSeries(chartData, TA = NULL, theme = "white")
EMA1 = addEMA(n = 10, col = "green")  #Adding Moving Average to chart
EMA2 = addEMA(n = 20, col = "blue")  #Adding Moving Average to chart
EMA1Vals = EMA1@TA.values  #Extracting Vals
EMA2Vals = EMA2@TA.values  #Extracting Vals
```

Remark 1 *Quantmod, has a whole bunch of functions which add all different kinds of technical indicators (TA) to charts.*

Then we convert MA's to xts and combine with the original AORD data = chartData—.

```
Series1 = as.xts(zoo(EMA1Vals, order.by = index(chartData)))
colnames(Series1) = "MAs"
Series2 = as.xts(zoo(EMA2Vals, order.by = index(chartData)))
colnames(Series2) = "MA1"
chartData = cbind.xts(chartData, Series1, Series2)
head(chartData, 2)

##            AORD.Open AORD.High AORD.Low AORD.Close AORD.Volume
## 2008-02-01      5717      5888     5714       5882   890030700
## 2008-02-04      5894      6058     5886       5922   865578100
##            AORD.Adjusted MAs MA1
## 2008-02-01          5882  NA  NA
## 2008-02-04          5922  NA  NA
```

Note that the beginning MA values don't exist as the first value in the series can only be caculated when there are enough lags available, e.g. MAs will only begin after 10 periods, as it has 10 lags.

1.2 Market Data, Trade and Portfolio Classes

Following other finance libraries, I have broken down the parts of the trading algorithm into the following logical pieces, which are implemented as classes:

- Market Data. This contains data inputs, and interface to other classes.
- Trades. These objects contain info about trades that is not dynamic market data. Notionals, TradeType. Also need functions to Price, Value given market data.
- Portfolios. This just collections of trades.

There's a couple of other classes I've added whose purpose I'll describe as we go.

We load the code that defines the classes

```
source("R/PortfolioClasses.R")
```

Make sure working directory is set correctly or won't load.

Continuing with "Main.R" code, let's look at how to build objects of these classes and what they do. We build an object **MD** of the **MarketData** class,

```
MD = MarketData(chartData)  #Create Market Data
```

This is just a class that contains our market data. It is a bit redundant as all our code is in R, but will provide the bridge when we implement in other languages. I.e. we'll construct data in R becuase it's easy, then we can the MarketData class to convert to form usable by C++/Python internal code we devlelop.

Next we build **T1**, **T2** objects of the Trade class I've defined.

```
T1 = Trade(Name = "Cash", Type = "Cash", Notional = 100)
T2 = Trade(Name = "AORD", Type = "Eq", Notional = 100)
```

So far I've only defined simple "Cash" and "Eq" types, and forgotten to include an argument for trade date info.

- "Cash" always has price = 1
- "Eq" has takes price from 'Close' of a MarketData object.

In the future we can make more complicated trade types like: futures, swaps, options, etc. These will have a lot more parameters, and much more complicated pricing formulas.

Remark 2 *Pretty much all of the high tech pricing libraries, like quantlib, fit in here. This is a good example of how OO seperates logical parts. If we want to swap in a different pricing library, then it will be only at this point that we need to redesign the interface.*

Now to Price/Value trades, we need to do it against a time slice of market data. For this reason I created the **MarketDataSlice** class, which is combined with Trade objects to value and price.

```
MDSlice = MarketDataSlice(MarketData = MD, TimeIndex = 1)  #Create MarketData time slice
Value(T1, MDSlice)

## [1] 100

Value(T2, MDSlice)

## [1] 588230
```

- Value of $T1 = 100$ as it was constructed with $Notional = 100$ it is of type "cash" and so always has price = 1.
- Value of $T2 = 5882.3$ as it was constructed with $Notional = 100$ it is of type "Eq" and so price = Close of the AORD index for time index 1 = 5882.3, which we can see if we look a few chunks of code back when we constructed the data (Let's just not worry about whether AORD index is a price or not).

Again, having a whole class just to slice the MarketData objects is a bit over the top for this simple example, but for more complicated examples, we may need to use the market data to create complicated objects with which to price, which we might want to defer till we actually want to compute a price.

For example, with swaps, the MarketData object will contain timeseries of all the swap rates etc. To price we'll need to create curve objects. IF we have a large timeseries, then if we created a curve for each time point in the market data we might blow up the memory (stackoverflow!). However, if we leave curve construction to the MarketDataSlice class, then we can run algo's over timesteps and chuck out each curve when we go to the next step in the algo loop.

The above code chunk demonstrates how the **MarketData** and Trade objects interact. We can then combine trades into a **Portfolio** object.

```
TradeList = list(T1, T2)
Port1 = Portfolio(Name = "Port1", Trades = TradeList)
print(Port1)  #Overloaded print for Porfolio

## [1] "Portfolio Name: Port1"

##   TradeName Type Notional
## 1      Cash Cash      100
## 2      AORD   Eq      100
```

Note in the above

- I've put the trades into a R list object. They way I've defined the Porfolio contructor, you have to do this, even for only a single Trade object. In robust production level code you would have type checking that would throw an error if this wasn't the case. In C++, the code won't even compile if data types don't match.
- I've overloaded 'print' for the portfolio class, to give a nice summary table. Should probably have a 'TradeData' field.

Then similar to creating a MarketDataSlice and valuing a trade, we make a **PortfolioSlice** object and define functions **Price, Value** that apply to it.

```
time = 1  #Pice time
PortfolioSlice = PortfolioSlice(MD, Port1, time)  #Create Portfolio slice
Price(PortfolioSlice)  #Query slice for Price

## Cash AORD
##    1 5882

Value(PortfolioSlice)  #Query slice for Value

##   Cash   AORD
##    100 588230
```

Note I have slightly different interface for valuing Portfolio's and Trades. Have to think a bit about this in a final version.

1.3 TradeStrategy Classes and Running Strategy

So far we haven't defined anything that will actually run our strategy. The above classes are not specialised to running strategies and can be used for other tasks, such as evaluating risk profiles for hedging, etc. This is what you want from OO. Reusability of code for logical chunks in different contexts.

To implement strategy we define load the the TradeStrategy classes.

```
source("R/TradeStrategyClasses.R")
```

This file implements a class **TradeStrategy**, which is described as follows.

- You construct **TS**, a **TradeStrategy** object, from a MarketData object, an initial portfolio Portfolio object, and an initial time.
- There is a class (aka member) function "updSig" which looks at the data and Portfolio at a given time step and generates a trade signal for the period. **This function defines the trade strategy**. E.g. for MA momentum, you buy or sell depending on if there was a crossover at that point in time.
- There is an "updPortfolio" class function that adds trades to the portfolio depending on what the "updSig" function says. For MA momentum this is adding a buy/sell trade of a given notional at that date. For a delta hedging strategy it would be adding trades so that delta of portfolio = 0.
- There is a "runStrategy" class function, which loops the "updPortfolio" function of the MarketData object and collects the results.
- There is a "Results" data member.

This is demonstrated in "Main.R". Initialise an empty portfolio with an initial cash trade of Notional =0.

```
Cash = Trade(Name = "Cash", Type = "Cash", 0)
Port_MAtest = Portfolio("Port_MAtest", list(Cash))
```

Initialise TradeStrategy object, $TS1$, with market data object MD as above, and with initial time=21 such that both the MA series exist.

```
TS1 = TradeStrategy(Port_MAtest, MD, 21)
Time = TS1$CurrentTime
# Check MA series exist
TS1$MarketData$Data[(Time - 1):Time, c(4, 7, 8)]

##            AORD.Close  MAs  MAl
## 2008-02-29       5675 5728 5720
## 2008-03-03       5511 5712 5713
```

I've picked an initial time so that there is a crossover right at the start. We can check this by running the "updSig" class function

```
updSig(TS1)

## [1] "sell"
```

Now we check if $TS1$ updates itself for the "sell" signal

```
print(TS1$Portfolio)  #only cash in Portfolio
```

```
## [1] "Portfolio Name: Port_MAtest"

##   TradeName Type Notional
## 1      Cash Cash        0
```

```
TS1$CurrentTime  #Current time index
```

```
## [1] 21
```

Run update and we should see a trade

```
TS1 = updatePortfolio(TS1)  #Run portfolio update
print(TS1$Portfolio)
```

```
## [1] "Portfolio Name: Port_MAtest"

##   TradeName Type Notional
## 1      Cash Cash   551070
## 2    Trade2   Eq     -100
```

```
TS1$CurrentTime  #Current time index has been advanced
```

```
## [1] 22
```

And we see that a new trade with with Notional = -100 has beeb added, ie a "sell", and that we take the value at of the 100 Notional we sold and add it to the cash Notional.

Total Value of the portfolio is still = 0, but when the "price" of AORD changes, and price of Cash staying constant =1, we will get PL for the portfolio.

So now let's run the strategy over all the time periods

```
TS1 = TradeStrategy(Port_MAtest, MD, 21)
TS1 = runStrategy(TS1)
```

which I've collected into a "Results" data member of the TS1 object.

```
head(TS1$Results, 5)
```

```
##    Time Value Signal
## 1 13941     0   sell
## 2 13942     0   hold
## 3 13943  3150   hold
## 4 13944  3910   hold
## 5 13945 -2120   hold
```

1.4 Plotting Results

The last bit of code is just displaying results. Just looks up results for timeseries of Value of portfolio and for when trades occour and does plots.

```
# Find where Trade Events occured
TradeEvents = which(TS1$Results[, "Signal"] != "hold")  #What indexes were trades at
TD = as.Date(TS1$Results$Time)[TradeEvents]  #Convert to date stamp
TradeDate = index(TS1$MarketData$Data)[TradeEvents]
TradeSigs = TS1$Results[TradeEvents, "Signal"]  #Get TradeSigs
```

Merge Portfolio Value ts with price for plotting

```
ResZoo = zoo(TS1$Results$Value, order.by = as.Date(TS1$Results$Time))
ResZoo = merge(ResZoo, chartData)
```

Caculate where to draw trade lines, and format labeling of charts

```
TradeDatesZooPlot = domain[which(domain %in% TradeDate)]
numberTix = 20
spacing = floor(length(domain)/numberTix)
marks = domain[seq(1, length(domain), spacing)]
labs = format(marks, "%d%b%y")
```

Do the results plots

2 Thoughts

We want to develop some system that can handle all types of strategies and all types of data. Following other finance models I think good basic classes for all later projects would be:

- Trade Class. Data will all be non-market,e.g.
  - trade date, trade type notional, bond:coupon, payment frequ, swap: strike, coupfreq. info on what market data type it needs to value.
  - Class functions (members) would be get trade info, price trade(market data input), value trade, calc appropriate greeks for trade type etc
- Market Data Class.
  - Data: raw loaded from bbg/reuters/etc, e.g. bondyields, swaprates, fx, etc
  - DerivedData: swap curves, bond curves, (think we use class inheritence for this e.g have inherited "swap market data", "bond market data" inherited classes)
  - TechnicalData: Stuff we might need for strats, ie moving averages, kalman filters, momentum trackers, etc - again might want to use inheritance
  - Class Members: load data from source to MD object, create derived MD like swap/bond curves, generate technical data from raw

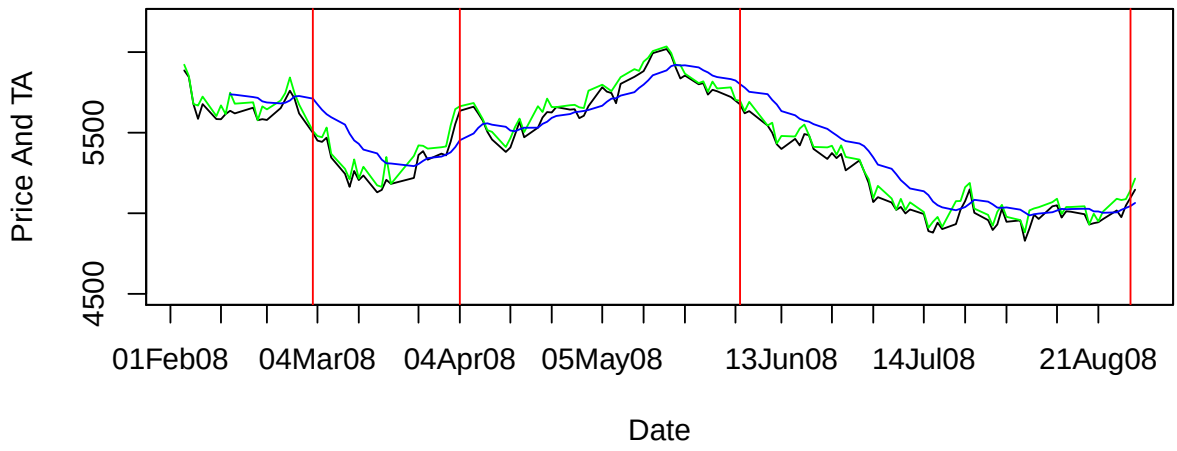
We can then add some more simple classes to combine the above basic classes to produce useful info:

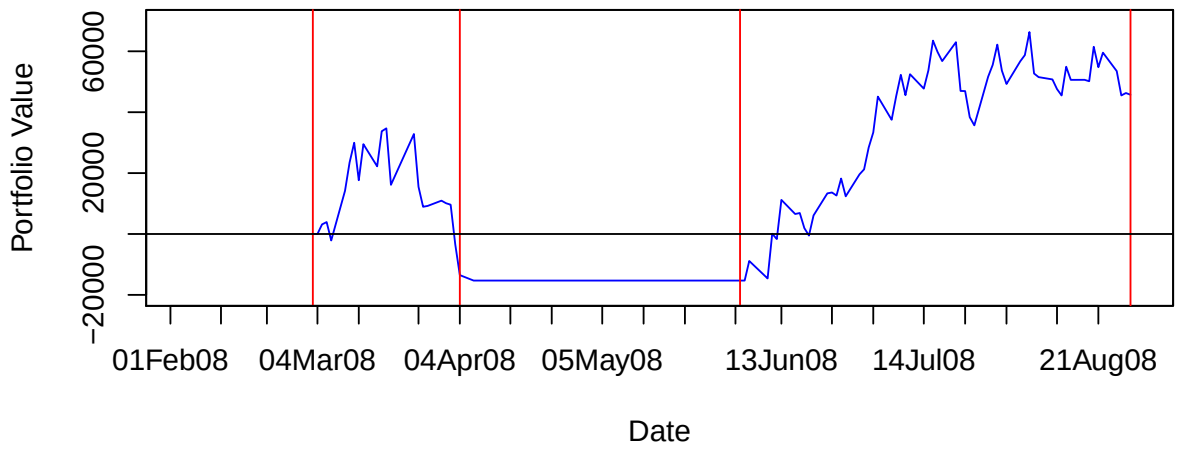
- Portfolio
  - Data: list of trades in portfolio
  - Members: aggregate info function, e.g. portfolio val, greeks, trade history profile etc
- PortfolioSlice - combining Portfolio and MD object at given time value to give all info at that time

```
split.screen(figs = c(2, 1))

## [1] 1 2

screen(1)
plot.zoo(ResZoo[-1, c(4, 7, 8)], ylim = c(4500, 6200), screens = c(1, 1, 1),
    col = c("black", "green", "blue"), xaxt = "n", xlab = "Date", ylab = "Price And TA")
axis(side = 1, at = marks, labels = labs)
abline(v = TD, col = "red")
screen(2)
plot.zoo(ResZoo[-1, 1], ylim = c(-20000, 70000), screens = c(1), col = c("blue"),
    xaxt = "n", xlab = "Date", ylab = "Portfolio Value")
abline(v = TD, col = "red")
abline(h = 0, col = "black")
axis(side = 1, at = marks, labels = labs)
```





- Data: portfolio object, market data object, timeValue
- Members: functions that apply Portfolio/Trade value functions to MarketData object at given time slice to produce Value, greeks, at that time.

So far our classes are pretty generic and versatile - can use outside strategy testing. For strategy testing we define one more class

- Strategy Tester
  - Data: MarketData and Portfolio objects, stratResults
  - Members: signalGenerator - this would generate signal to trade given MD and Portfolio object at each given instant in tiem. E.g momentum tell to buy/sell, mean reversion when to fade, delta hedging how much to hedge
  - Member: updatePortfolio - this would update portfolio given signal
  - Member: run strategy - loop through time applying signaGenerator and update Portfolio to run strategy.
  - Member: Results/Diagnostics, use stratResults to gen info, ie PL, sharpeRatios, TradeProfiles, etc

If we were just looking at one strategy type then the above would be overkill, you could just write a standalone script.

But if we start wanting to look at comparing a bunch of different strategies then we're going to writing a lot of standalone scripts with very similar operatios, loading data, valuing trades, looking at PL and sharpe ratios.

This is what OO is all about - breaking programmes into logical chunks and only specialisng the bits we need to. For strategy testing I think it's the signal generating function. When you work out what this will require the rest of the bits should be easy.

Also a big advantage of moving to OO is you can put in error checking easily - ie you can say what each object needs to work, ie swaptrade objects would need swapcurve objects to values so when you combine into portfolioSlice you could have a check that tells you if you have the right pieces for everything to function. A step we put in the production building stage rather than protyping I think.

Anyway, I've done the above for an example using Moving average crossovers on AORD index from yahoo finance.