Quantitative trading and backtesting

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CERN Finance Club

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Contents

1) Introduce quantitative trading and backtesting from a theoretical point of view

2) Show how to implement in Python a backtesting environment for simple trading strategies

Quantitative trading

- Also called *systematic trading* or *algorithmic trading*
- Creates a set of rules to generate trade signals and risk management of positions with minimal manager intervention
- Attempts to identify statistically significant and repeatable market behaviour that can be exploited to generate profits
- Low-frequency (weekly, daily) through to high-frequency (seconds, milliseconds...)

Quantitative trading system

- Four major components of a quantitative trading system:
  1) Strategy identification
  2) Strategy backtesting
  3) Execution system
  4) Risk management

- Focus on first two, last two won't be covered here

Strategy identification

- Research strategies in blogs, forums, journals, etc. For example:
  - Journal of Investment Strategies
  - Quantpedia.com
  - Many more (GIYF)
- Many of these strategies are either not profitable anymore or only slightly profitable (they get “crowded” or “arbitraged away”)
- Key to making them highly profitable is to build on them, e.g. adapt them to new market conditions or optimise their parameters

Strategy identification

- Two main categories of strategies:
  - **Trend-following:** Trades on *momentum*, i.e. on the basis of the slow diffusion of information
  - **Mean reversion:** trades on the deviation of a *stationary* time series (price or spread) from its expected value

- Range of trading frequencies
  - **Low frequency trading** (LFT): days-years
  - **High frequency trading** (HFT): intraday
  - **Ultra high frequency trading** (UHFT): seconds-milliseconds

- High frequency trading requires detailed knowledge of market microstructure (how the order book and exchange work)

Backtesting

- Once a strategy is identified, need to test its performance using historical data as well as out-of-sample data

<u>Data</u>

- Many types: fundamental, OHLC, sentiment, news
- Many frequencies: intraday, daily
- Many instruments: equities, futures
- Many sources: many are expensive, but there are a few good free sources, e.g. Yahoo Finance, Quandl
- Qualities of good data:
  - Clean and accurate (no erroneous entries)
  - Free of survivorship bias (see next slide)
  - Adjusted for stock splits and dividends

Backtesting

Biases

- Biases tend to inflate performance. A backtest is likely an upper bound on the actual performance
- Optimisation bias
  - Over fitting the data as a result of too many free parameters
  - Strategy will fail with real data
- Lookahead bias
  - Introduction of future information into past data
  - e.g. using the day's high/low, calculating a parameter using data that would not have been available at the time
- Survivorship bias
  - Using only instruments which exist at present
  - Companies that went bankrupt would have made your performance worse

Backtesting

Transaction costs

- Backtest performance is inflated if transaction costs are not modelled appropriately
- Commissions/fees
  - A commission is paid to the broker for every transaction
  - Bid-ask spread is also important, especially for illiquid instruments
- Slippage
  - Price difference between time of trade signal and time of order fill
  - Depends on the volatility of the asset and the latency between the trading system, the broker and the exchange
  - Especially important for HFT
- Market impact
  - Placing large orders can “move the market” against you
  - May want to break the transaction into smaller chunks

Execution and risk management

- The last two components of a quantitative trading system would entail a whole other talk. Very briefly:

Execution system

- Generates trades in real time
- Provides an interface to the broker (e.g. via an API)

Risk management

- Decides how to act on trade signals
- Controls leverage
- Assigns capital to trades or strategies as optimally as possible

Analysing performance

Some common measures of performance

- **Compounded growth rate**
  - Usually annualised, gives the average annual return

$$\text{CAGR} = \left(\frac{\text{Ending Value}}{\text{Beginning Value}}\right)^{\left(\frac{1}{\#\text{ of years}}\right)} - 1$$

- **Volatility**
  - Usually annualised, given by the standard deviation of annual returns
  - Measure of risk

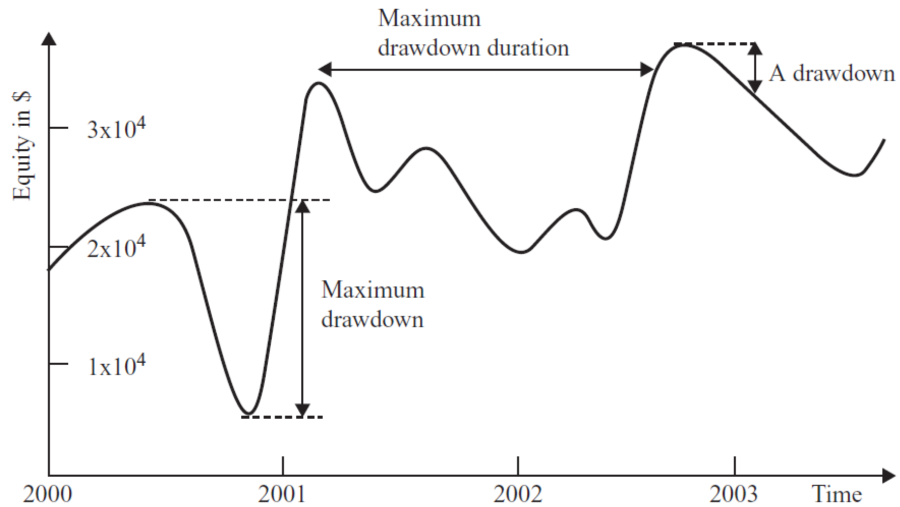
- **Sharpe ratio**
  - Measure of reward/risk ratio
  - Usually annualised and measured with respect to a benchmark b (e.g. risk-free rate or S&P500)

$$S = \frac{\mathbb{E}(R_a - R_b)}{\sqrt{\mathrm{Var}(R_a - R_b)}}$$

Analysing performance

Some common measures of performance

- **Drawdown**
  - A period of time in which equity is below the highest peak so far
  - Can calculate *maximum drawdown* and *maximum drawdown duration*



- **Alpha, Beta**
  - Fit a straight line (*security characteristic line*) to strategy returns against the returns of a benchmark (e.g. S&P or "the market")
  - Beta is the gradient – the variance/correlation with respect to the market i.e. gives a measure of *systematic risk* (want beta ~ 0)
  - Alpha is the intercept – the *excess return* over the market, i.e. a measure of performance (want large positive alpha)

Python backtester

- Let's put this into practice with Python

- My backtesting code:
  - www.github.com/Xtian9/QuantCode *
  - Disclaimer: Very simple and incomplete
  - Feel free to use it or contribute!

- Makes use of pandas, numpy, and matplotlib

- Employs vectorised calculations as opposed to an 'event-loop' (so less realistic as a simulation, but handy for doing quick research)

* Inspired by:
www.quantstart.com
www.github.com/quantopian/pyfolio

Python backtester

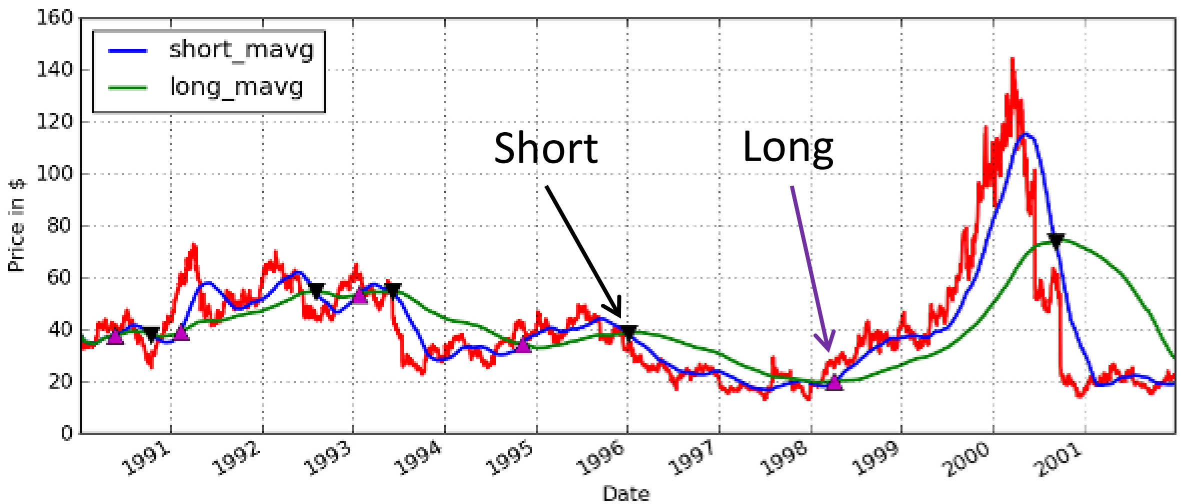
Components of the backtester

- **Data handler**
  - Downloads OHLC data from Quandl
- **Strategy**
  - Generates signals for each day
  - +1 long, -1 short, 0 cash (no position)
- **Portfolio**
  - Generates/rebalances positions
    - e.g. assign equal dollar weights to all assets
  - Computes returns (potentially for risk management)
- **Analyser**
  - Analyses the performance of the backtest
    - e.g. equity curve, Sharpe ratio, etc.
- Still missing: transaction costs, risk manager...

Moving average crossover

- Let's look at a "hello world" example strategy
  - *Moving average crossover*
  - This is a momentum strategy

- Strategy rules:
  - Create two simple moving averages (SMA) of a price series with different lookback periods, e.g. 9 days and 200 days
  - If the short MA exceeds the long MA then "go long"
  - If the long MA exceeds the short MA then "go short"



Config file

`backtests/macross/macross_cfg.py`

- Choose trading parameters: tickers, dates, frequency, window lengths

```
symbols = ['AAPL']
qcodes = ['GOOG/NASDAQ_'+s for s in symbols]
date_start, date_end = "2010-01-01", "2015-12-31"
frequency = "daily"
datas = ['Close']

short_window = 9
long_window = 200
```

- Initialise strategy, portfolio, analyser and backtest classes

```
strategy = MovingAverageCrossoverStrategy(short_window,long_window)
portfolio = EqualWeightsPortfolio()
analyser = [PerformanceAnalyser()]
backtest = Backtest(strategy = strategy,
                    portfolio = portfolio,
                    analyser = analyser,
```

- Run the backtest!

```
backtest.run()
```

Data handler

- The `DataHandler` class fetches data from Quandl and returns a pandas DataFrame of prices, e.g.

```
              AREX    WLL     SPY
Date
2012-01-03   31.23  49.20  127.49
2012-01-04   31.27  50.25  127.63
2012-01-05   31.92  51.83  128.10
2012-01-06   32.04  51.84  127.82
2012-01-09   32.39  52.10  127.99
...            ...    ...     ...
2012-12-24   24.56  42.49  142.35
2012-12-26   24.73  43.04  141.75
2012-12-27   24.32  42.57  141.56
2012-12-28   24.07  41.67  140.03
2012-12-31   25.01  43.37  142.41
```

- The `Backtest` class then creates empty `signals` and `weights` DataFrames that need to be filled by the `Strategy` and `Portfoflio` classes, respectively

Strategy class

`strategies/macross.py`

- Create a `MovingAverageCrossoverStrategy` that inherits from `Strategy`

```
class MovingAverageCrossoverStrategy(Strategy):

    def __init__(self, short_window=None, long_window=None):
        super(MovingAverageCrossoverStrategy, self).__init__()
        self.short_window = short_window
        self.long_window = long_window
```

- Implement a `generate_signals` method that fills in the `signals` DataFrame

```
    def generate_signals(self):
        super(MovingAverageCrossoverStrategy, self).generate_signal

        mavg_short = pd.rolling_mean(self.prices, self.short_window)
        mavg_long  = pd.rolling_mean(self.prices, self.long_window)

        self.signals[mavg_short > mavg_long] = 1
        self.signals[mavg_long > mavg_short] = -1
```

Portfolio class

`portfolios/equalweights.py`

- Create a `EqualWeightsPortfolio` that inherits from `Portfolio`

```
class EqualWeightsPortfolio(Portfolio):

    def __init__(self):
        super(EqualWeightsPortfolio, self).__init__()
```

- Implement a `generate_positions` method that fills in the `weights` DataFrame

```
    def generate_positions(self):
        super(EqualWeightsPortfolio, self).generate_positions()
        nassets = len(self.weights.columns)
        self.weights.loc[:,:] = 1. / nassets
```

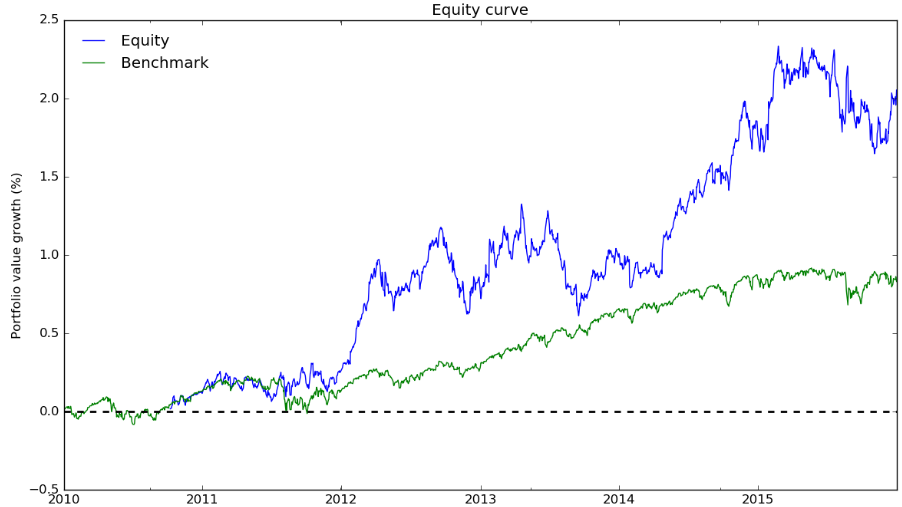
- If weights sum to 1, total return of portfoflio is the weighted average of the assets' returns

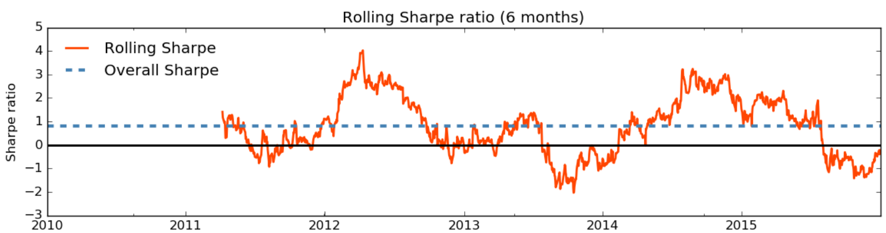
Analyser class

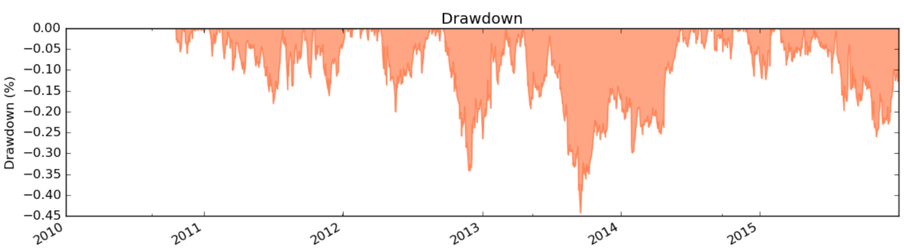
- `analysers/performance.py`
- Generic `Analyser` that computes performance measures like Sharpe ratio, drawdown etc. and makes performance plots like equity curve etc.
- Can also create and add additional `Analyser` sub-classes to the backtest

```
Start date: 2010-01-01
End date: 2015-12-31

Symbols: ['AAPL']

APR                   24.79%
Volatility            26.33%
Total return          205.20%
Total return bmark    82.94%
Alpha                 0.00
Beta                  0.43
Sharpe ratio          0.79
Information ratio     0.48
Max DD                44.23%
Max DD duration       285
```

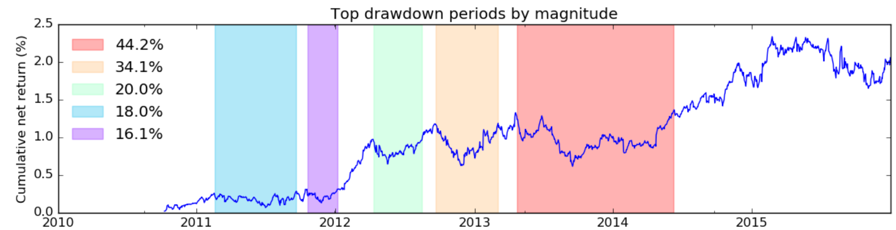
Analyser class

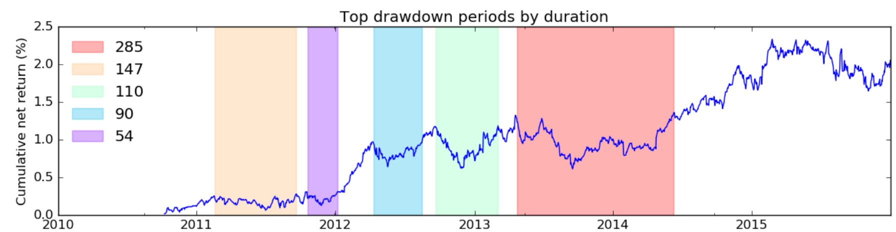


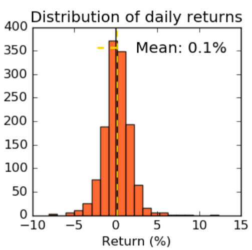




- Performance plots







Outlook

- Would like to expand on this to build a more sophisticated quantitative trading system with many improvements:
  - Event-driven backtesting
  - Realistic handling of transaction costs
  - Risk management framework
  - GUI?
  - Real time execution
- As well as doing actual quant research
- Would anyone like to work on this together?
  - We could set up a *quant trading* or *quant research* arm within the club

Bibliography

- Michael H. Moore

  www.quantstart.com

- Ernest P. Chan

  Quantitative Trading: How to Build Your Own Algorithmic Trading Business

- Ernest P. Chan

  Algorithmic Trading: Winning Strategies and Their Rationale