DNN'S FOR TIMESERIES

Predicting the 2016 Presidential Election

By: Avi Thaker

A Lecture for Professor Gary Evans Markets and Modeling Class

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ABOUT ME

- Data Scientist - Microsoft
  - Deep learning models for customers
  - Implemented a semantic knowledge graph for Ads
- Trader
  - Fully automated trading systems
    - Crypto and Equity Markets
  - Research Driven Process
  - Deep learning models for Audio/Text/Timeseries

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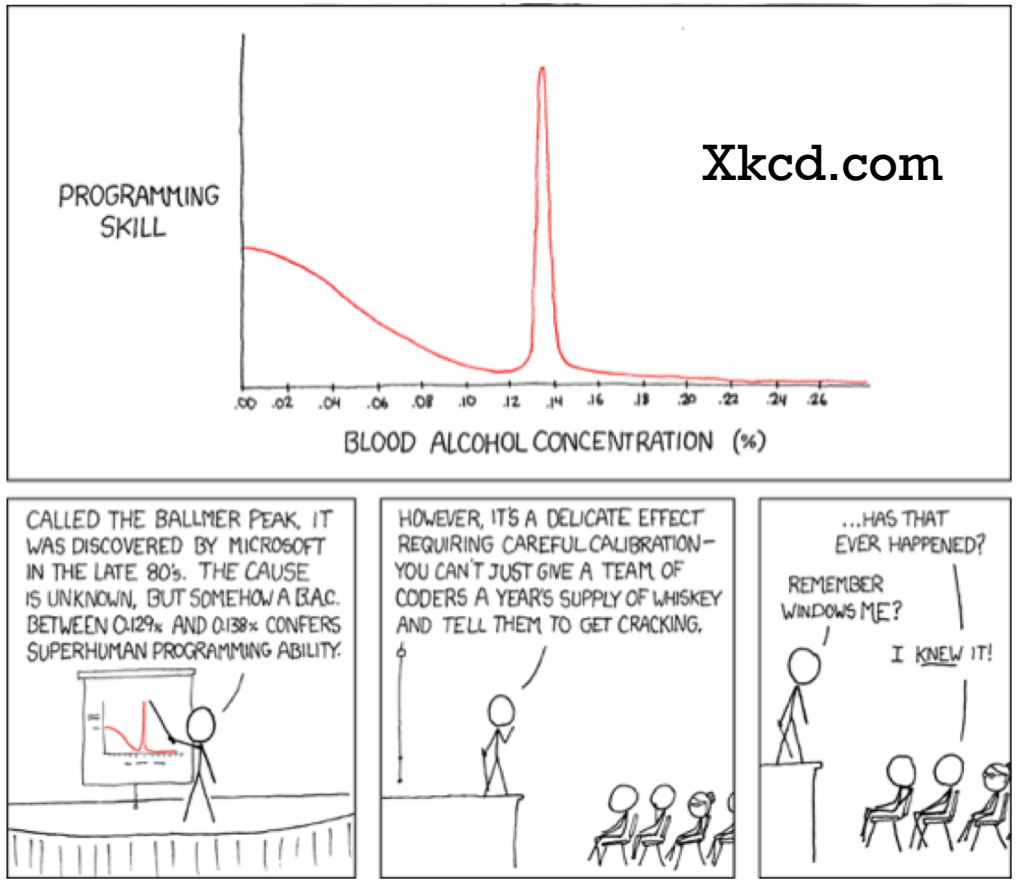
Microsoft



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LECTURE HIGHLIGHTS

- Algorithmic Trading at a Glance
- Introduction to Neural Networks
- Predicting the 2016 Presidential Election
- Careers in Data Science / AI
- Building your own prop-shop (time permitting)

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ALGORITHMIC TRADING AT A GLANCE

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THE EFFICIENT MARKET HYPOTHESIS

- Market efficiency causes prices to incorporate and reflect all relevant information
  - Impossible to "beat the market"
- Warren Buffett? Citadel? Virtu?
  - *When filing for its IPO in March 2014, it was disclosed that during five years Virtu Financial made profit 1,277 out of 1,278 days, losing money just one day*.

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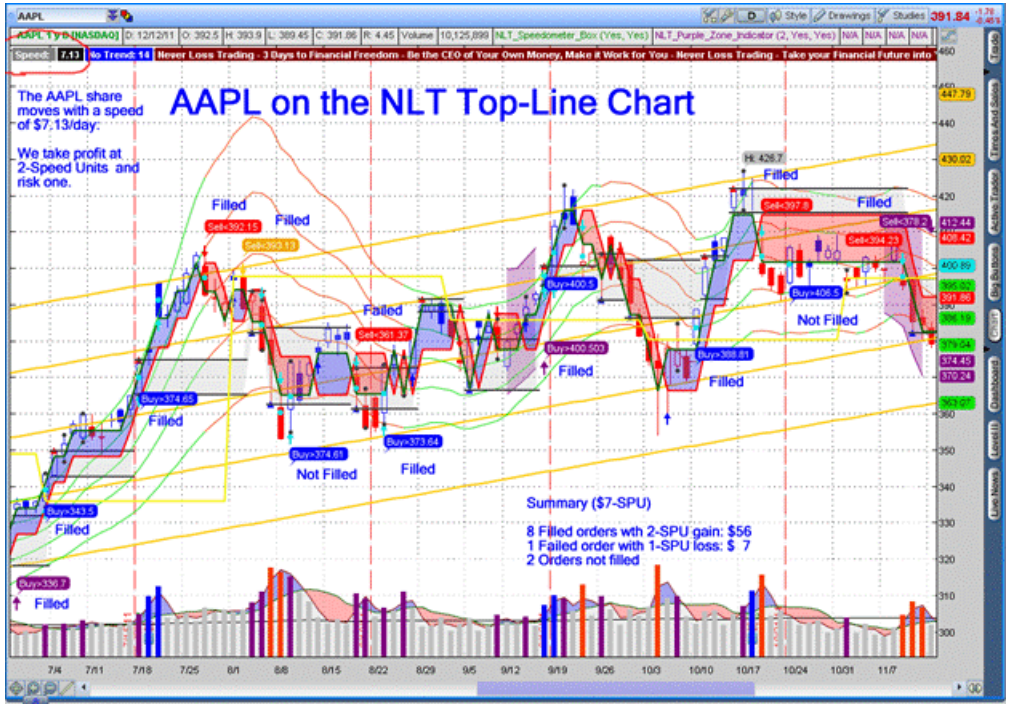
WHAT IS ALGORITHMIC TRADING

- The use of electronic platforms for entering trading orders with an algorithm which executes pre-programmed trading instructions whose variables may include timing, price, or quantity of the order.



http://neverlosstrading.com/Algorithmic%20Trading.html

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KINDS OF STRATEGIES

- Arbitrage
- Alpha Taking – Predicting the market
  - Mean reverting
  - Momentum
- Market Making
- Index/Pairs Trading
  - Can be part of any of the above

*More info can be found in the appendix for all of these kinds of trading strategies

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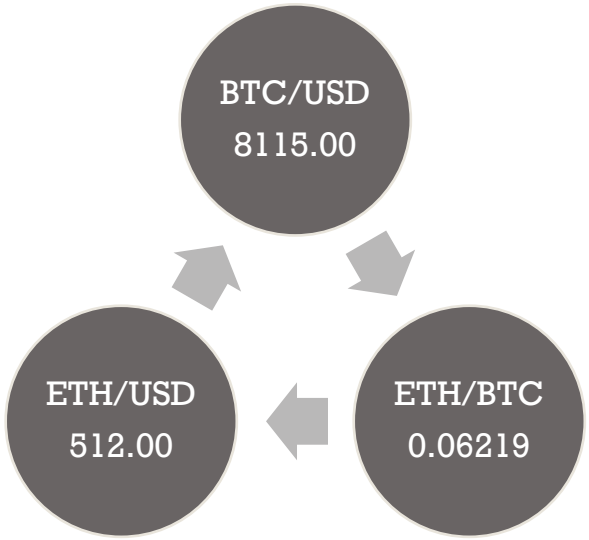
ARBITRAGE (ARB)

Inter Exchange Arb (Triangle)



8115 USD -> 1 BTC
1 BTC -> 16.079 ETH
16.079 ETH -> 8232.83 USD
Net: 117.83 USD

Cross Exchange Arb

```
Console output Crypto
[0.0404%, 'BTC/USD', <ccxt.gdax.gdax >, <ccxt.bitstamp.bitstamp>]
[0.0332%, 'ETH/USD', <ccxt.gdax.gdax>, <ccxt.bitstamp.bitstamp>]
```

Buy BTC on GDAX transfer it to Bitstamp
Sell BTC for USD on Bitstamp
Net: 3.28 USD

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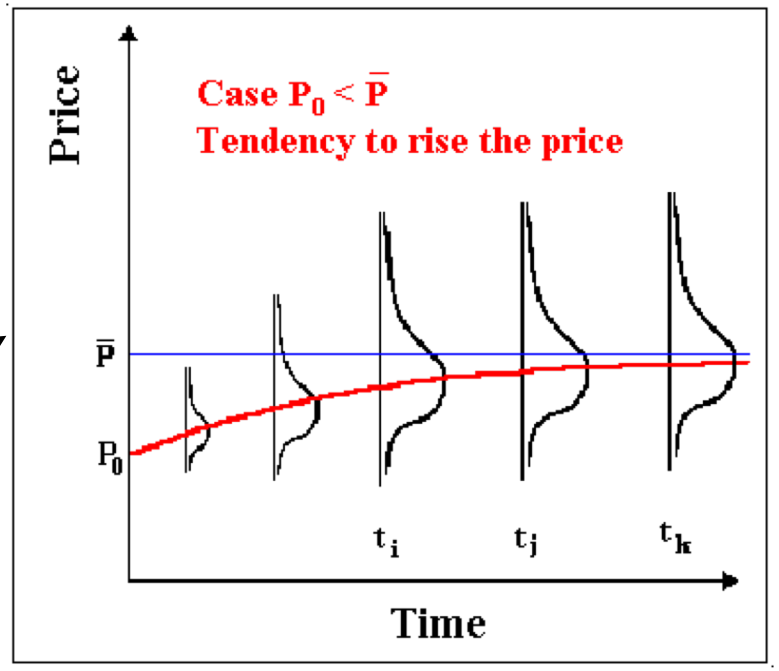
ALPHA TAKING

- Believes the product will move in one direction
- Mean Reverting – price reverts back to a "average" price, Bollinger Bands
  - Stochastic Math
- Trend following / Momentum
  - Price will move in one direction
  - Impulse response filters



http://marcoagd.usuarios.rdc.puc-rio.br/revers.html

Stockcharts.com

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MARKET MAKING

- Increase liquidity – rewarded with the spread
- Can be dangerous in times of volatility

Bids	Price	Asks
	100.03	2,1
	100.02	3,7,8
	100.01	5,2,15
	100	1,2,5
1,2	99.99	
2,5,8	99.98	
3,8,1,5,3	99.97	
2,3	99.85	

- Lots of machine learning, think Bayesian networks, and neural networks
- The focus is on market microstructure

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TECHNICAL INDICATORS

- Technical indicators are mostly **useless** on their own
- Must identify a market phenomenon and statistically validate it
- Simplicity and understandability usually are better

- Accumulation/Distribution (AD)
- Average Directional Movement (ADX)
- Absolute Price Oscillator (APO)
- Aroon Oscillator (ARO)
- Average True Range (ATR)
- Bollinger Band (BBANDS)
- Directional Movement Indicators (DMI)
- Exponential (EMA)
- Fill Indicator (FILL)
- Ichimoku (ICH)
- Keltner Channel (KC)
- Linear Regression (LR)
- Moving Average Convergence Divergence (MACD)
- On Balance Volume (OBV)
- Relative Strength Indicator (RSI)
- Parabolic Sar (SAR)
- Simple Moving Average (SMA)
- Triple Exponential Moving Average (TEMA)
- Triangular Moving Average (TRIMA)
- Triple Exponential Moving Average Oscillator (TRIX)
- Time Series Forecast (TSF)
- TT Cumulative Vol Delta (TT CVD)
- Ultimate Oscillator (ULTOSC)
- Volume Delta (Vol)
- Volume Weighted Average Price (VWAP)
- ….
- ….

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INTRODUCTION TO NEURAL NETWORKS

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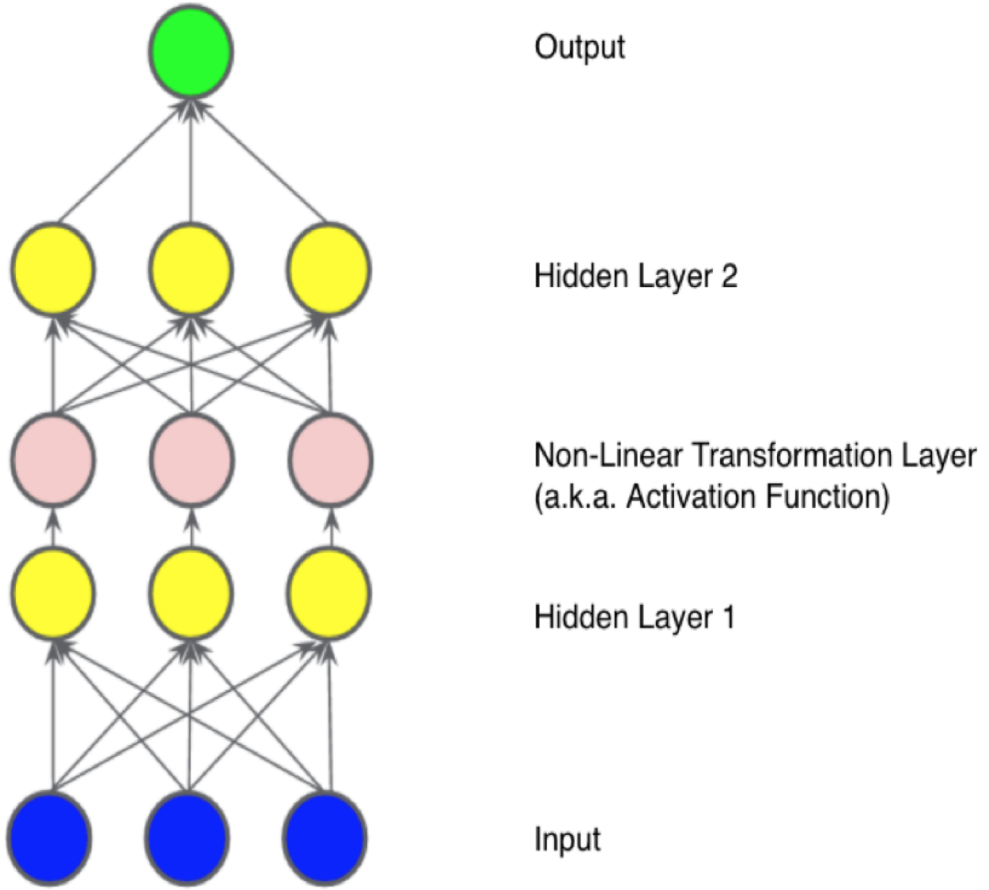
https://www.youtube.com/watch?v=bxe

ANATOMY OF A NEURAL NETWORK

- Set of nodes organized in layers
- Set of weights representing the connections between each layer
- Set of biases one for each node
- Activation function that transforms the output of each node in a layer
- Can be thought of as a black box mapping inputs to outputs



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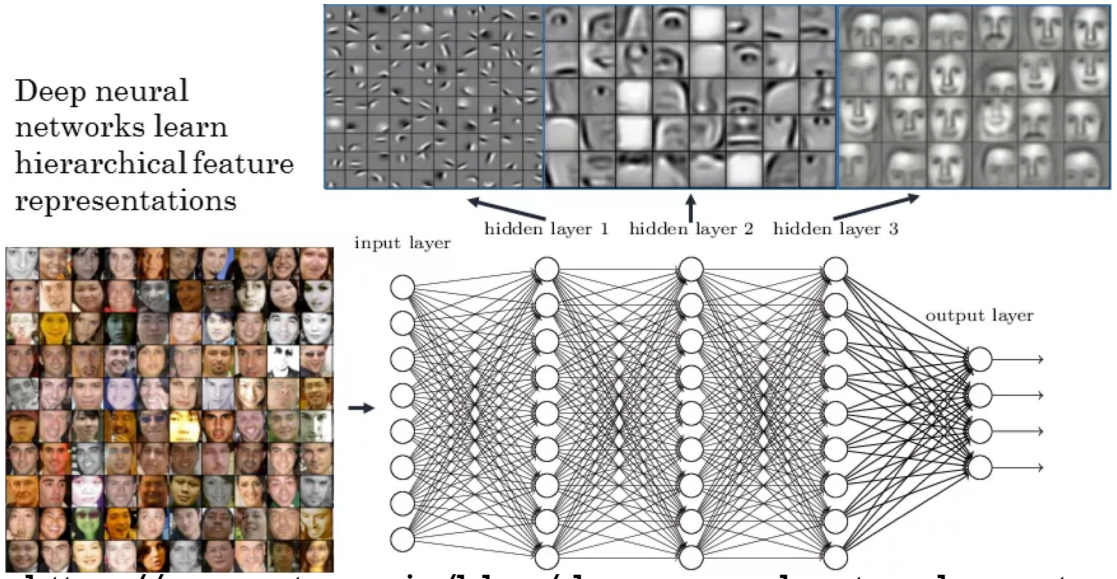
CLASSICAL ML VS DEEP LEARNING

- Classical ML
  - Code up features to some model
- Deep Learning
  - Model learns the useful features/feature combinations by looking at raw input
- Garbage in -> garbage out
  - Models are highly dependent on data quality no matter the quality of the network architecture



https://www.strong.io/blog/deep-neural-networks-go-to-the-movies

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APPLICATIONS OF NEURAL NETWORKS

- Image/Video
  - Classification, Detection, Segmentation
- Text
  - Search, classification, summarization
- Speech
  - Text to speech, speech to text
- Timeseries
  - What will the future value of the stock be?
- Many More
  - Risk analysis, medicine, etc.

https://www.youtube.com/watch?v=xW2hpkoaIiM

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PREDICTING THE 2016 PRESIDENTIAL ELECTION

This will provide the basics and principles can be applied to predict other events like Brexit. In practice I built a more general framework to predict big events, and their expected market impact.

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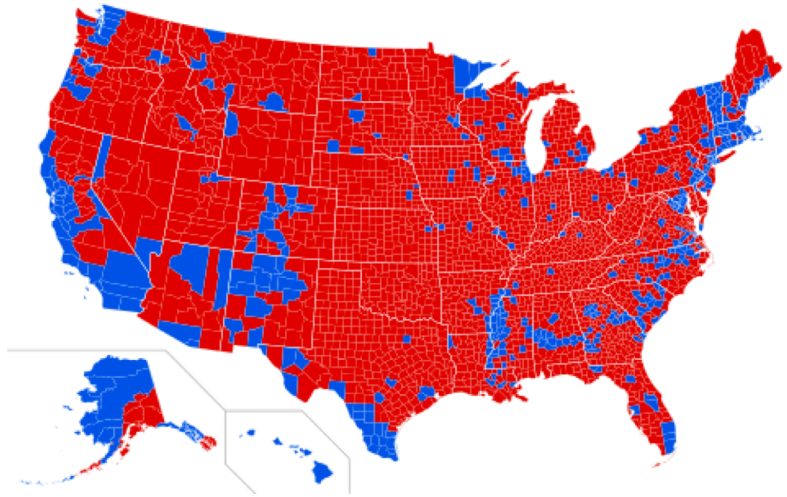
OVERVIEW

- Use a DNN and features to predict the Trump election and the expected market reaction
- Python utilizing Tensorflow
- https://github.com/athaker/econ_136
- Identify the sources of data and the resulting outputs
- What features do you think are most important to the model?



Candidate	Party	Electoral Votes	Popular Votes
Donald J. Trump	Republican	**304**	62,980,160
Hillary R. Clinton	Democratic	227	**65,845,063**
Gary Johnson	Libertarian	0	4,488,931
Jill Stein	Green	0	1,457,050
Evan McMullin	Independent	0	728,830

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DATA ENGINEERING

- Arguably the most important thing in Deep/Machine Learning
- High quality labels and features drive model performance
  - Perfect features would be forward looking
- Personally, I look for model insensitivity*
- Look for model biases
  - Forward looking bias
  - Curve fitting bias
  - Survivorship bias
  - Psychological bias

*I do not have a formal rigorous approach to this, but I strive for models to get similar results with similar features, i.e. features mean something

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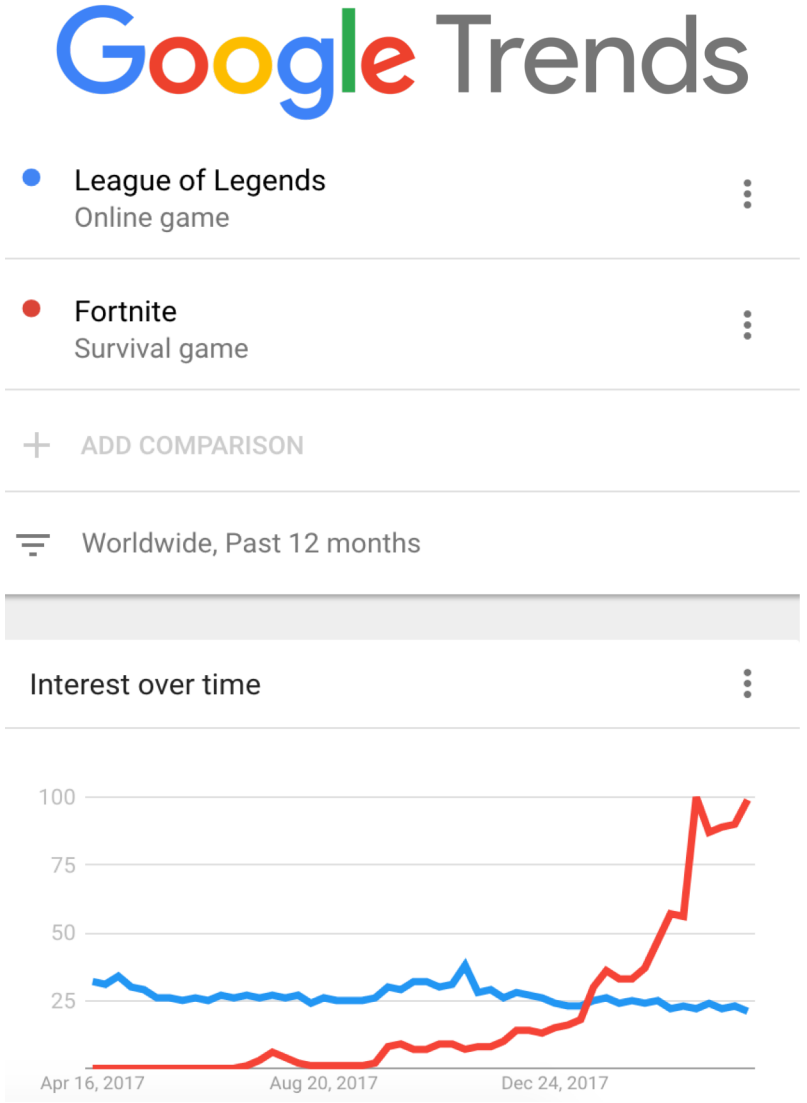
OBTAINING DATA

Mechanical Turk: Build an API for humans to generate you labels



- Better and data will give you better models

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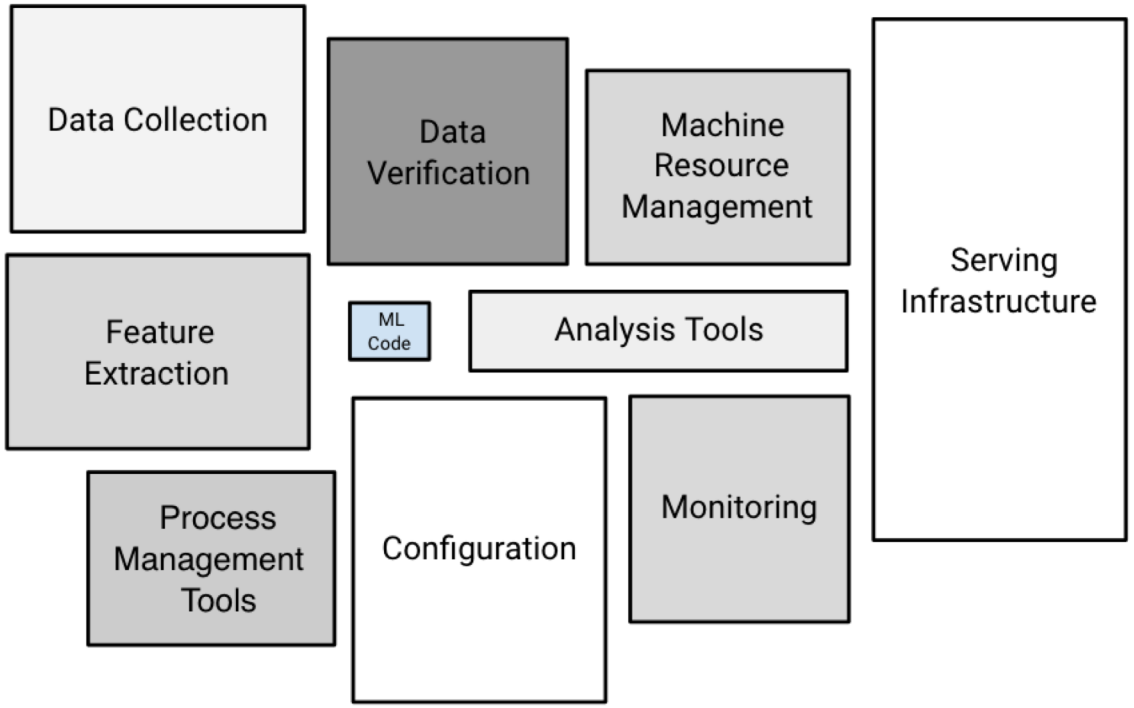
ML/DL IS ONLY A SMALL FRACTION OF THE WORK



https://developers.google.com/machine-learning/crash-course

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CAREERS IN DATA SCIENCE / AI

What can I do with this new found knowledge?

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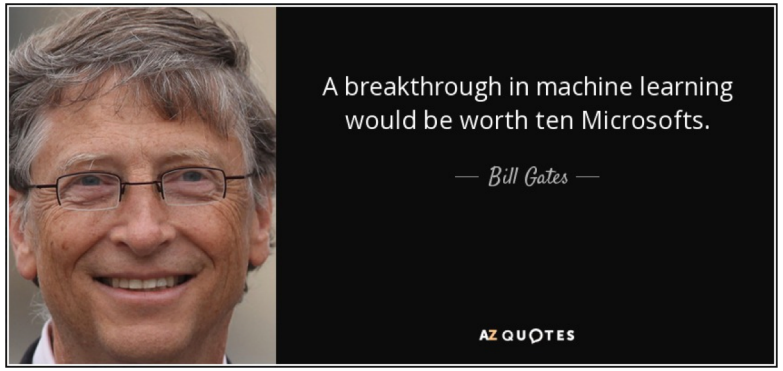
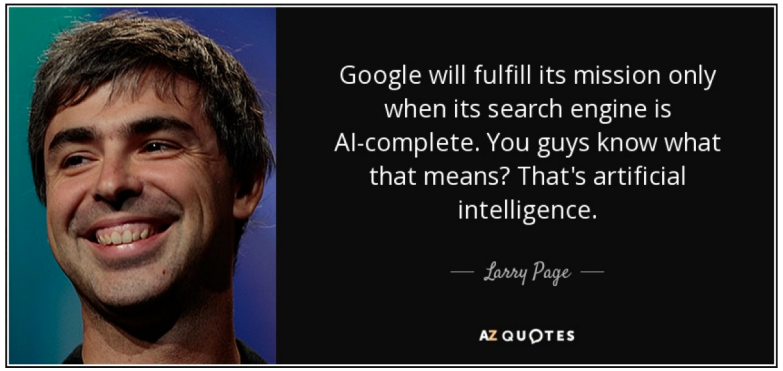
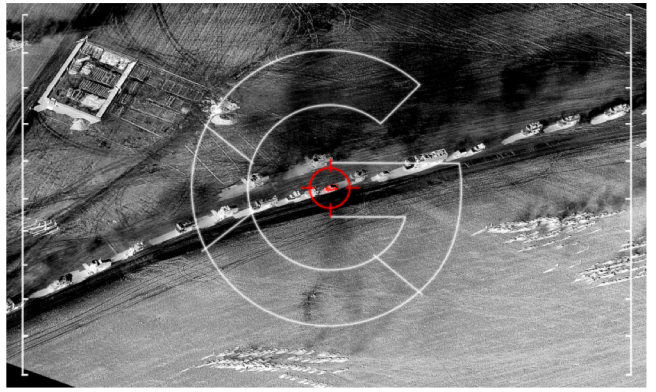
HOT TOPICS

- Finance hires “quants”
- This is the hot topic right now, tech, finance, … all sectors hiring like crazy
- Smart interaction with the world
  - Smart Cars, Search
- 3rd Party Data
  - Satellite imagery parsing for hedge funds, quant focused approach
- Big name companies say it is their focus
  - Google, Amazon, Facebook, Microsoft
  - Microsoft “AI First” company now
- Think about and be careful what you build







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IMPORTANT TO KNOW

- Math
  - Linear Algebra
  - Statistics
- Programming
  - Python - Most used and developed in language
  - Tensorflow
  - Keras
  - Scikit Learn
  - C/C++
  - CUDA
- If path in Finance
  - Start trading and get a track record!
  - Math/Computer Science majors tend to be valuable over Economics/Business
- Read Papers and Blogs!

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GETTING STARTED: PROP SHOP / FUND

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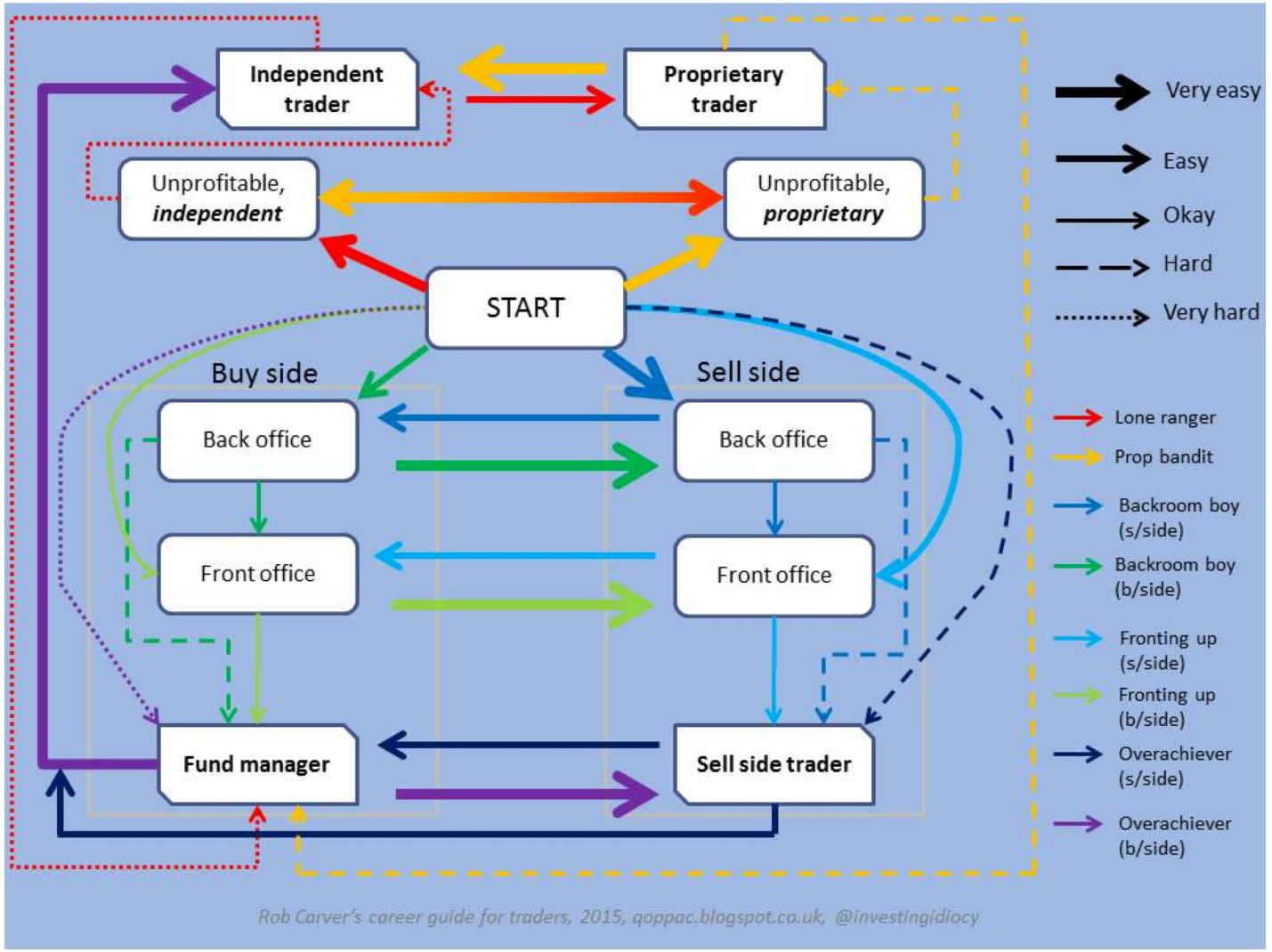
A VISUAL GUIDE

- Get started trading!
  - Start small
- Prove you can make money
- Higher Sharpe Ratio is more valuable
- Quantitative skills right now are incredibly important



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ONLINE RESOURCES: DATA SCIENCE

- Golden Standard - Andrew NG (Stanford)
  - https://www.coursera.org/learn/machine-learning
  - https://www.coursera.org/specializations/deep-learning
- Father of Deep Learning
  - https://www.coursera.org/learn/neural-networks (hardest)
- Google
  - https://developers.google.com/machine-learning/crash-course/ (easiest)
  - https://www.udacity.com/course/deep-learning--ud730
- Quantstart
  - https://www.quantstart.com/
- Wikipedia
  - https://en.wikipedia.org/wiki/Deep_learning

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ONLINE RESOURCES: TRADING

- Golden Standard
  - http://www.quantstart.com
- Execution Environment/Backtester/Community
  - https://www.quantopian.com
- Suggested intro trading platform / broker
  - www.interactivebrokers.com
- Data:
  - Yahoo Finance, Google Finance, Quandl
- Other:
  - https://qoppac.blogspot.com/
  - http://epchan.blogspot.com/

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QUESTIONS?

Ask me about:

Trading? DNNs? Crypto Currency? Crypto Mining? Life at Microsoft?

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APPENDIX: PERSONAL LEARNINGS

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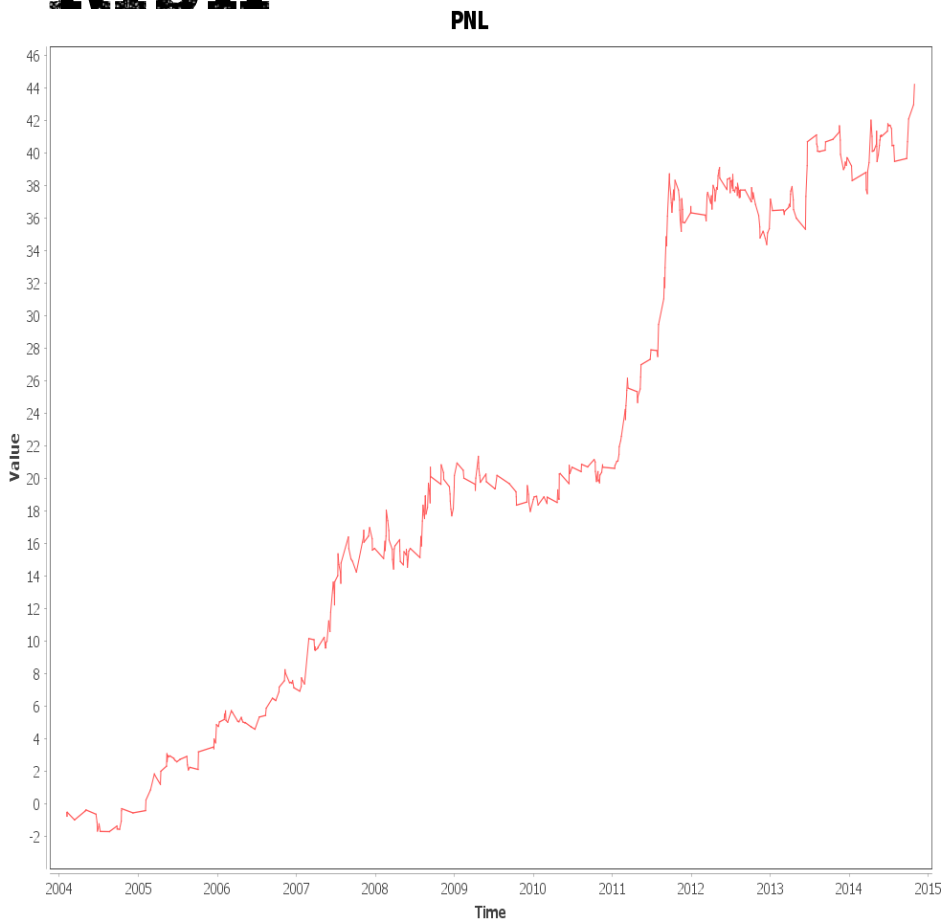
BACKTESTING A STRATEGY/RISK

- Provide evidence of profitability
  - Curve fitting/ optimization bias
  - In-sample vs out-of-sample
  - Forward looking bias
- Risk tolerance

Key Statistics

Average wins	:: 0.637 USD
Average loss	:: -0.438 USD
# Wins	:: 214
# Losses	:: 210
# Neutrals	:: 3
Win Rate	:: 0.501
PPC	:: 0.104USD
# Traded	:: 427.0
Ann. Sharpe	:: 2.335



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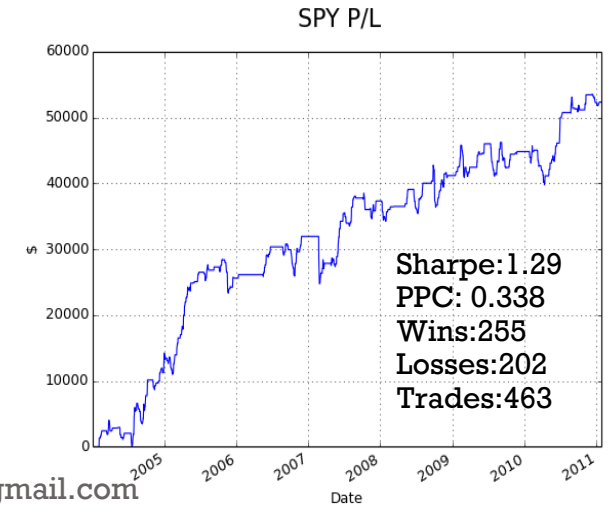
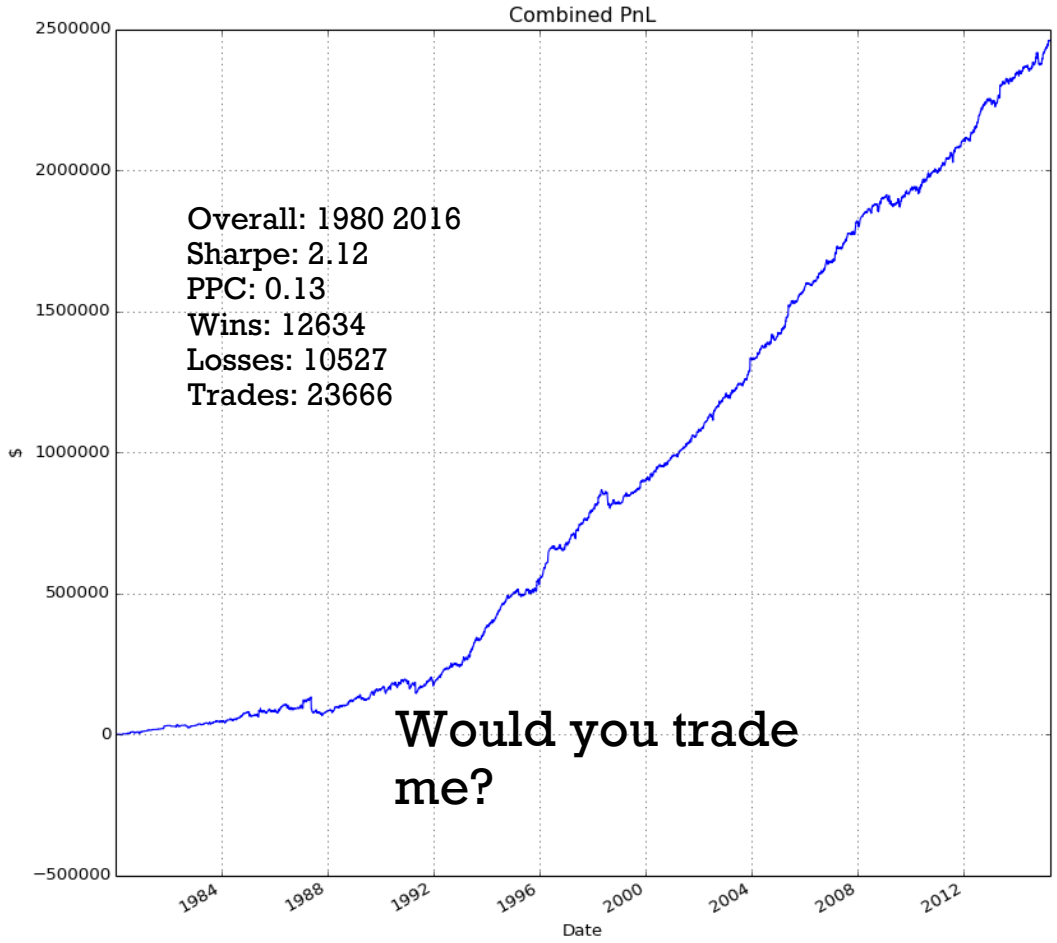
BACKTESTING

- Does the strategy work across many assets?
- How many years does it work for?
- Does it escape the bid-ask bounce?
- Risk Tolerance?
  - Maximum Drawdown?
- Fees? Trading frequency?





In Sample: SPY 2004-2010
Out of Sample: Assets Randomly Selected:
ADBE XLNX BBBY CFN EMC ADP AFL DE T SPLS DG ADS ALL MET CL PX WYN

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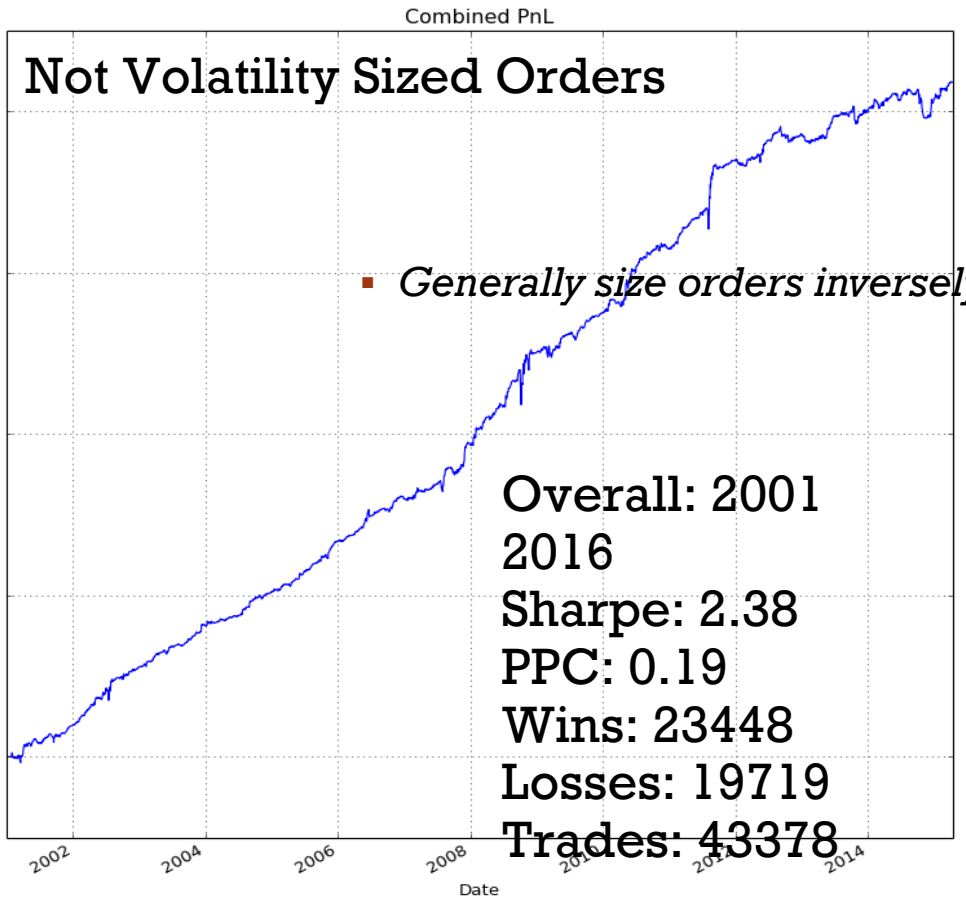
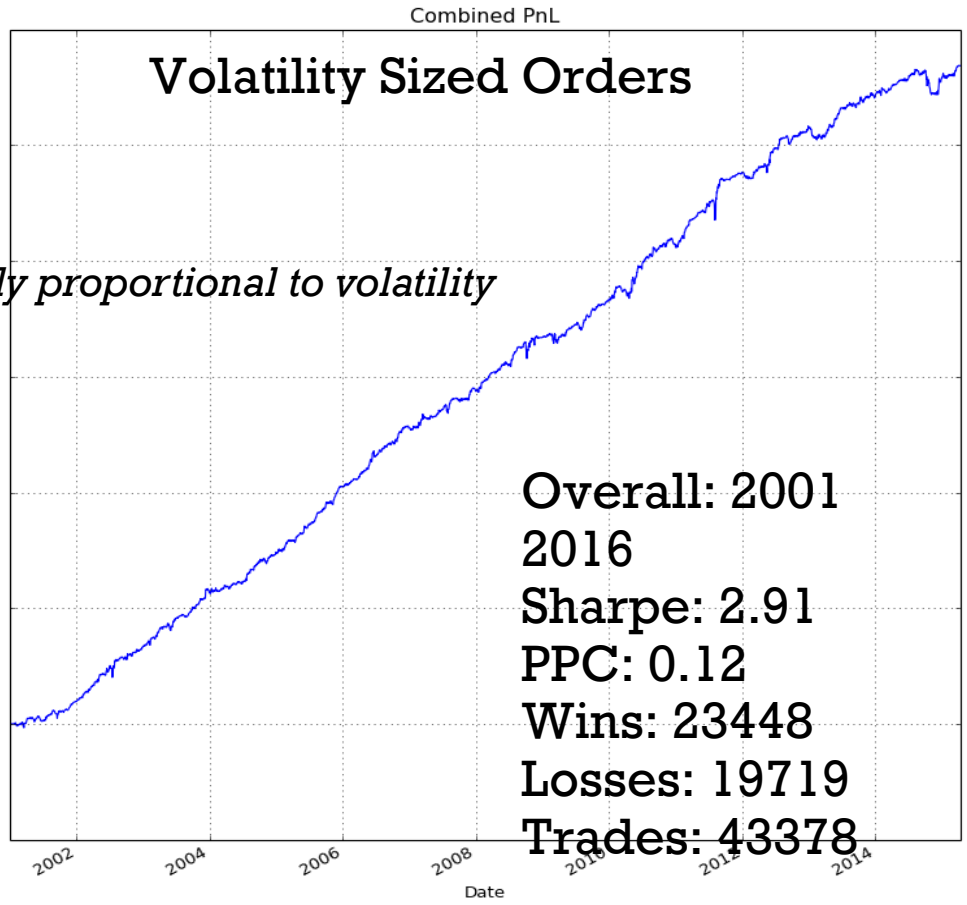
ORDER SIZING



- *Generally size orders inversely proportional to volatility*



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GENERAL TIPS

- This is not a get rich quick scheme
- Finding alpha is hard, do not get discouraged
- Drawdown are painful, be careful with leverage
- Trust your alpha (if you have some), strategies are usually simple
- Performance
  - Out of sample performance is generally ½ of in sample performance
  - Live trading performance is generally ¼ of in sample performance
  - Due to curve fitting, unexpected slippage, etc.
- Make sure you account for ***transaction fees*** and ***slippage*** and ***order sizes***
- Fun and exciting way to learn not only the markets but also computer science and math
- Data is your friend
- Build your own backtester/execution environment

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APPENDIX: MEAN REVERSION AND MOMENTUM

This section covers the details about statistical testing and a detailed look into how to test classically for a mean reverting or trending (momentum) timeseries.

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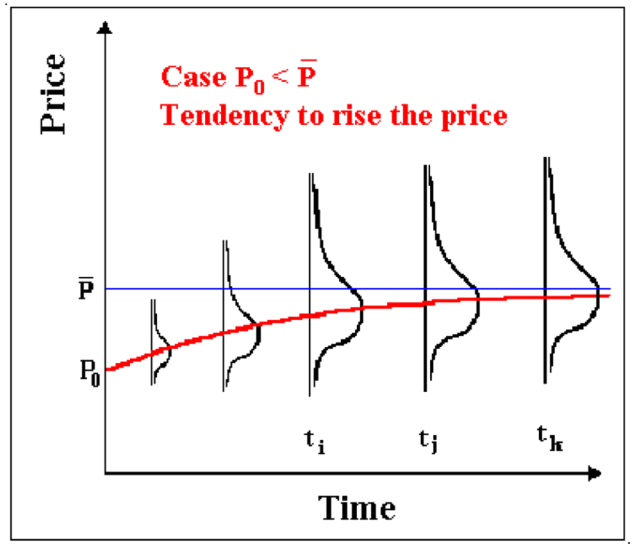
STATISTICAL TESTING

- Mean Reversion
  - A process that refers to a time series that displays a tendency to revert to its historical mean
  - More specifically: if the prices within the series move away from their initial value faster than that of Geometric Brownian Motion
  - Ornstein-Uhlenbeck process (a random walk has no memory)
- Momentum
  - The exact opposite of mean reversion
  - Movement away from the initial value faster than that of random walk
- Mean reversion and momentum go hand in hand, in identifying one you may identify the other
- Will cover two methods: Augmented Dickey-Fuller test, and the Hurst Exponent



Pictures From:
http://marcoagd.usuarios.rdc.puc-rio.br/revers.html
http://www.stockcharts.com

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STATISTICAL TESTING: TERMS

- Orenstein-Uhlenbeck SDE
- Change in price series in next time period is proportional to the difference between the mean price and the current price with Gaussian noise
- Motivates Augmented Dickey-Fuller (ADF) Test

$$\boldsymbol{dx_t = \theta(\mu - x_t)dt + \sigma dW_t}$$

$$\theta = rate\ of\ reversion\ to\ mean$$

$$\mu = mean\ value\ of\ process$$

$$\sigma = variance\ of\ the\ process$$

$$W_t = Wiener\ Process\ or\ Brownian\ Motion$$

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AUGMENTED DICKEY-FULLER (ADF) TEST

- Identify presence of a unit root in autoregressive time series
- Relies on the fact that if a price series has a mean reversion then the next price will be proportional to the current price
- Linear Model of Order p

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \cdots + \delta_{p-1} \Delta y_{t-p+1} + \epsilon_t$$

$$\alpha = constant$$

$$\beta = coefficient\ of\ time\ trend\ (long\ term\ drift)$$

$$\Delta y_t = y(t) - y(t-1)$$

- Testing null hypothesis: $\gamma = 0$
  - Indicates that process is a random walk ($\alpha = \beta = 0$)

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AUGMENTED DICKEY-FULLER (ADF) TEST

- Test statistic: sample proportionality / standard error of sample proportionality

$$DF_\tau = \frac{\hat{\gamma}}{SE(\hat{\gamma})}$$

- Negative number, and must be less than critical values to be significant
- Code `adf_test.py`

```
Calculated Test Statistic: -2.190010503128752 9
P-Value: 0.2098910250427564
# Datapoints: 2106
10%: -2.5675011176676956
5%: -2.8629133710702983
1%: -3.4334588739173006
```

Cannot reject null hypothesis, and unlikely to have found a mean reverting time series

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HURST EXPONENT

- A stochastic process is strongly stationary if its joint probability distribution is invariant under translations in time or space
  - Mean and variance of process do not change over time and do not follow a trend
- Hurst Exponent helps to characterize the stationarity of a time series
  - Reverting, trending, or neither
- Variance of a log price series to identify rate of diffusive behavior

$$Var(\tau) = \langle |\log(t+\tau) - \log(t)|^2 \rangle$$

- Since large τ, variance is proportional to τ for Geometric Brownian Motion

$$\tau \sim \langle |\log(t+\tau) - \log(t)|^2 \rangle$$

- If autocorrelations exist the relationship is not valid, but can be modified to include *2H* with the Hurst Exponent value H

$$\tau^{2H} \sim \langle |\log(t+\tau) - \log(t)|^2 \rangle$$

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HURST EXPONENT: MEANING

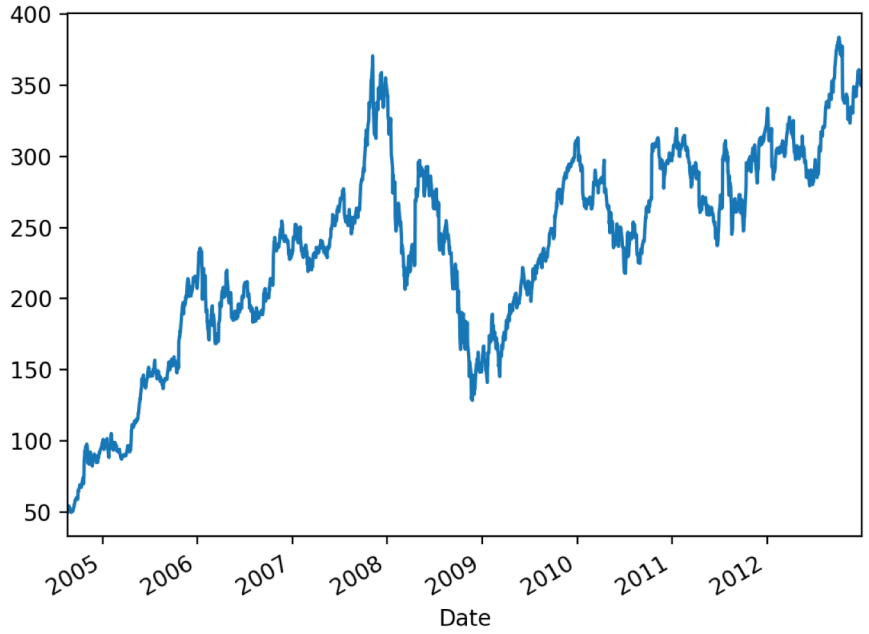
$H < 0.5$ mean reverting process

$H == 0.5$ GBM

$H > 0.5$ trending process

- Characterizes extent
  - Closer to 0 more mean reverting
  - Closer to 1 more trending

- Try different time periods, different stocks



Hurst(GBM): 0.498349157279
Hurst(MR): -6.26637088795e-05
Hurst(TR): 0.95964231812
Hurst(GOOG): 0.50788012279

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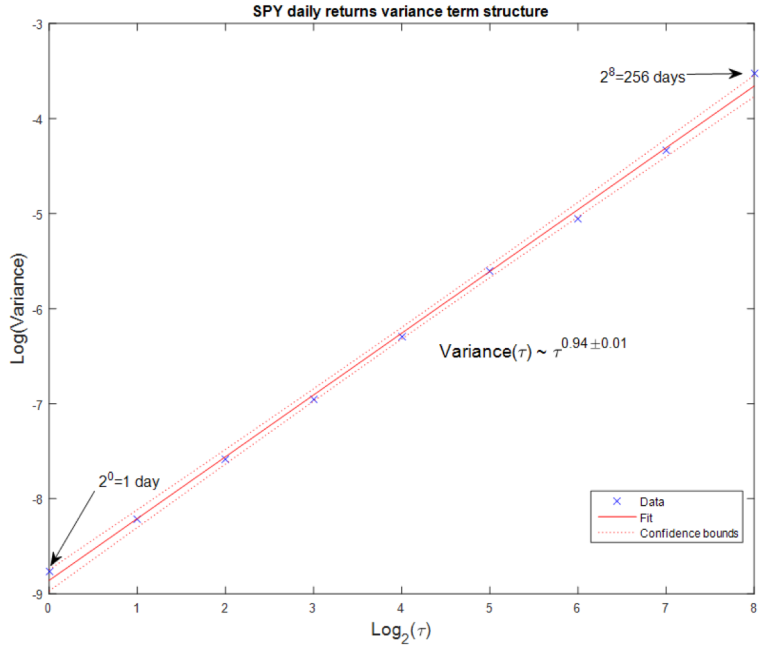
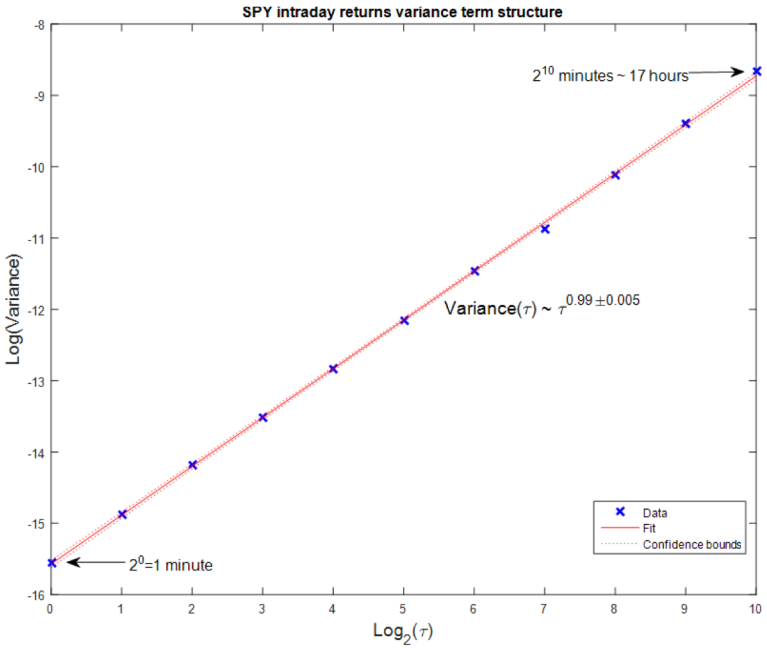
VARIANCE AND TERM STRUCTURE

- *Not included in code*
- Plot of $\log(Var(\tau))$ *vs* $\log(\tau)$ for SPY
  - Slope/2 is the Hurst exponent
  - Intraday
    - Returns of mid-prices from 1 minute to 2^10 minutes
    - $H = 0.494 \pm 0.003$; slightly mean reverting
  - Daily
    - Returns from 1 day to 2^8 days
    - $H = 0.469 \pm 0.007$; strongly mean reverting
- Mean reversion strategies should work better than intraday strategies on SPY





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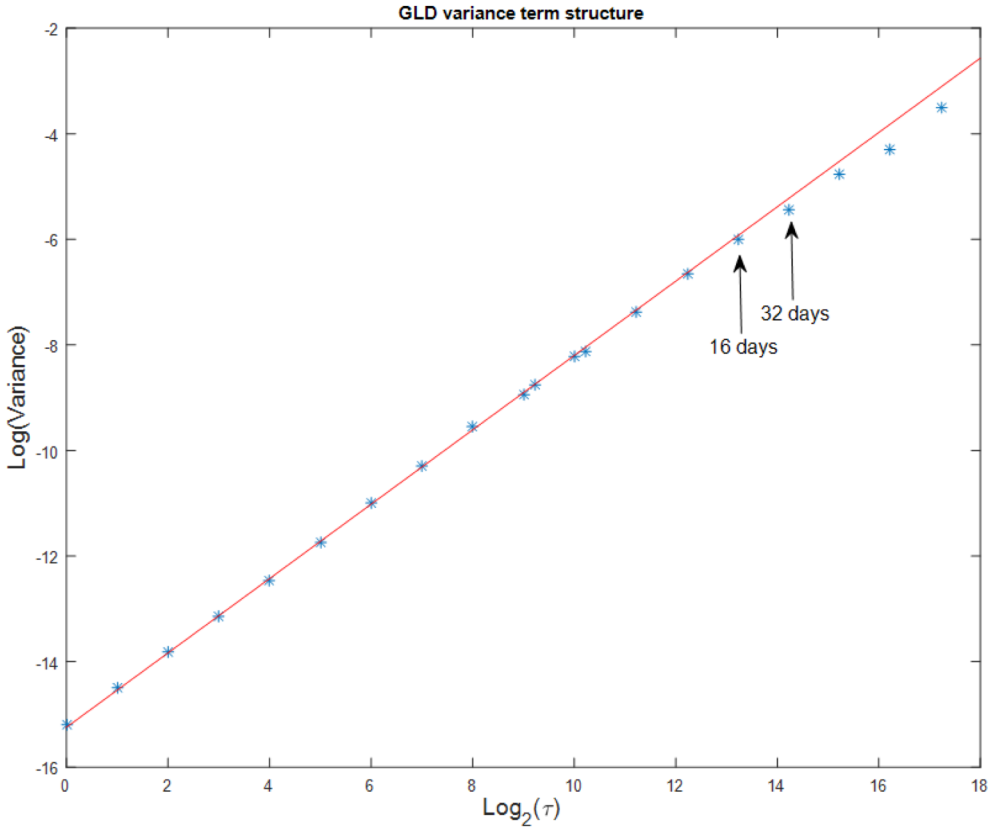
http://epchan.blogspot.com/2016/04/mean-reversion-momentum-and

VARIANCE AND TERM STRUCTURE: GOLD

- Intraday: $H = 0.505 \pm 0.002$
- Daily: $H = 0.469 \pm 0.007$
- 16-32 days volatilities drift from the regression
  - ***This is where we should switch from momentum to mean reversion strategies***



A Trending Example: USO

Intraday $H = 0.515 \pm 0.001$

Daily $H = 0.560 \pm 0.020$

Momentum strategies should work well here

http://epchan.blogspot.com/2016/04/mean-reversion-momentum-and-volatility.html

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APPENDIX: KINDS OF STRATEGIES

A Brief Introduction

HFT VS NON HFT

- HFT or High Frequency Trading, relies on quick algorithmic trading to capture small spreads or small alpha (less than 1 minute holds)
  - Difficult for the retail investor to get into
  - Extremely competitive
    - Fastest usually takes all profits
    - Makes up 70%+ of all trading volume
- Non HFT (trades of longer periods)
  - Easier for the retail investor to get into
  - Not as competitive
    - Smarter people make profits
  - This is our focus

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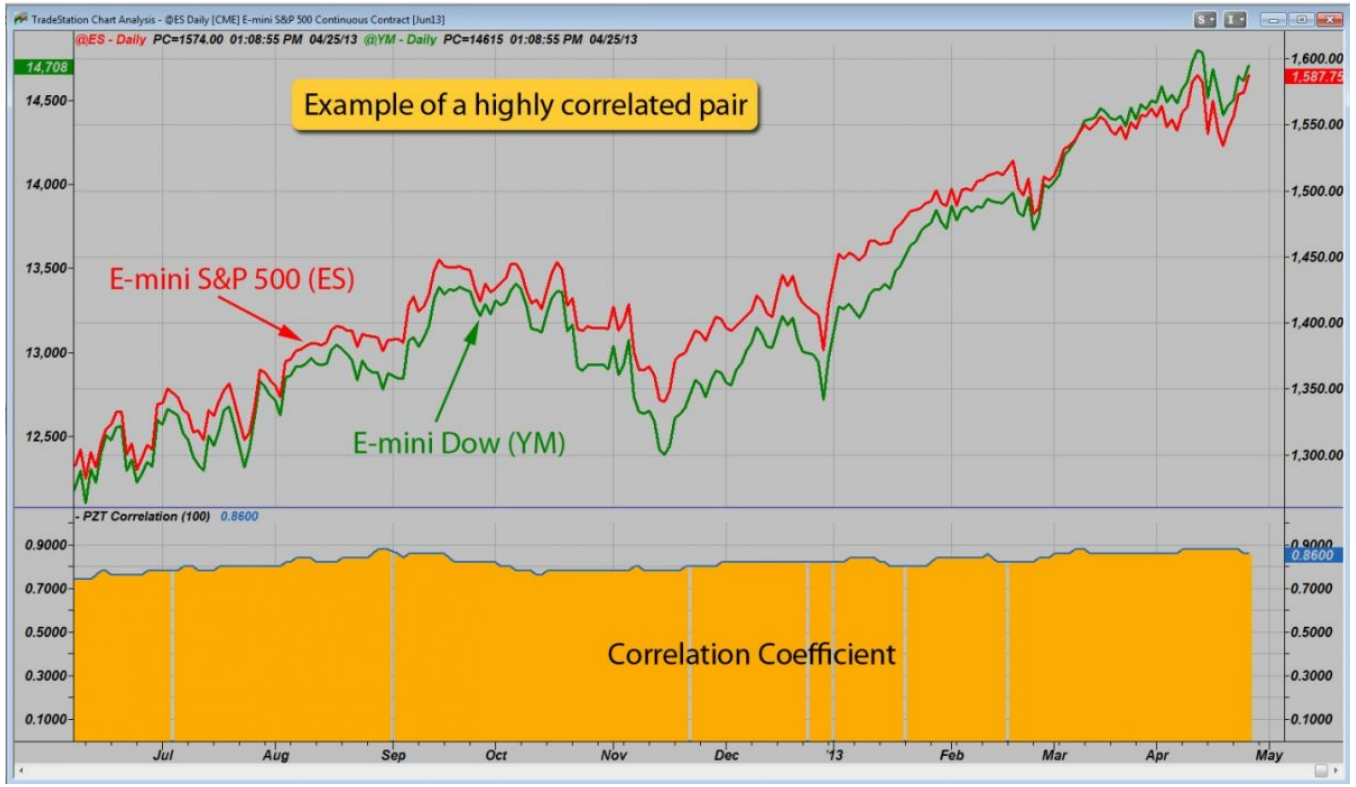
STRATEGY: PAIR TRADING

- Assumes two contracts move together
- Revert moves when one moves against the other
- Can be highly risky
  - 2007 Crash?
  - Spreads blow up
- Commonly used by Hedgefunds
- High usage of Kalman Filters, CADF (Co-integrated Augmented Dickey Fuller) tests, autocorrelation, etc.



http://www.investopedia.com/university/guide-pairs-trading/pairs-trade-example.asp

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STRATEGY DETAIL: COMMON SIGNALS
SIMPLE MOVING AVERAGE: SMA

- Mean of previous n periods
- Smooths data, easier to identify trends
- Common signal

$$SMA = \frac{p_M + p_{M-1} + \ \ldots + p_{M-(n-1)}}{n}$$

$$SMA_{current} = SMA_{previous} - \frac{p_{M-n}}{n} + \frac{p_M}{n}$$

$$p_i = price\ at\ given\ time$$

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STRATEGY DETAIL: COMMON SIGNALS
EXPONENTIAL MOVING AVERAGE: EMA

- Infinite impulse response filter
- Less lag than SMA
- Commonly used signal

$$\alpha = \frac{2}{n+1}$$

$$EMA_{current} = \frac{p_1 + (1-\alpha)p_2 + (1-\alpha)^2 + \cdots}{1 + (1-\alpha) + (1-\alpha)^2 + \ \ldots}$$

$$= EMA_{previous} + \alpha\left(p_{current} - EMA_{previous}\right)$$

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TRADING THE EMA

Enter Long: Close > EMA & Prev_Close > EMA_Prev
Enter Short: Close < EMA & Prev_Close < EMA_Prev

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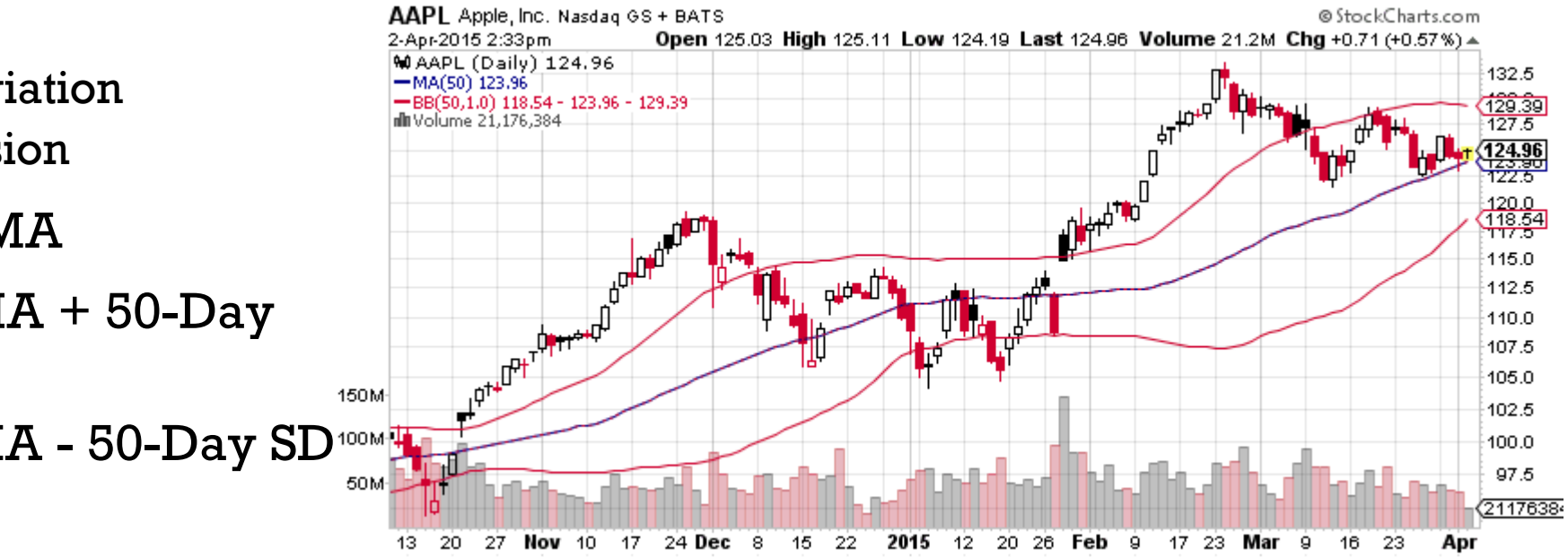
STRATEGY DETAIL: COMMON SIGNALS BOLLINGER BANDS

- Volatility Bands
  - Based upon standard deviation
  - Identifies points of reversion
- Middle Band = 50-Day SMA
- Upper Band = 50-Day SMA + 50-Day SD of Price
- Lower Band = 50-Day SMA - 50-Day SD of Price



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EXAMPLE: TRADING THE BOLLINGER BANDS

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ETF CREATION/REDEMPTION

- Authorized participant (market maker, intuitional investor, specialist) borrows stock shares and places them in a trust to form ETF **creation units** – bundles of stock units
- Trust provides shares to the AP, and shares sold to public on open market
- Redeeming ETF
  - Sell shares on open market
  - Form a creation unit and and exchange for underlying security
    - Tax efficient

Creation Unit	Last Trade	Bid	Ask	Size	Net	Percentage
AMD	13.7	13.69	13.7	100	1370	16.31%
INTC	35.16	35.16	35.17	100	3516	41.85%
AAPL	140.64	140.63	140.64	25	3516	41.85%
Creation Unit	**84.02**			**100**	**8402**	**100.00%**

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ETF/INDEX ARBITRAGE

Unit	Last Trade	Bid	Ask	Size	Net	Percentage
AMD	13.7	13.69	13.7	100	1370	16.31%
INTC	35.16	35.16	35.17	100	3516	41.85%
AAPL	140.64	140.63	140.64	25	3516	41.85%
Creation Unit	**84.02**	**84.01**	**84.03**	**100**	**8402**	**100.00%**

- This is the most common strategy employed by most quant firms and banks
  - Jane Street, AQR, Jump Trading
- You need to be **fast** or have **flow**
  - Some of you may have done this in the game
- Arbitrage happens when ETF trades at a discount or premium to the NAV
  - ***Institutional:*** When ETF price > NAV, the AP will sell shares it received during creation and make a spread between the cost of the assets it bought for the ETF issuer and the selling price from the ETF shares. AP can also buy the underlying shares that compose the ETF directly at lower prices, sell ETF shares on the open market at the higher price, capturing the spread.
  - ***Individuals:*** When the ETF is selling at a premium (or discount), individuals can buy (short) the underlying securities in the same proportions and short (or buy) the ETF. Limited by liquidity and spread
    - If inside the spread need to know if the ETF goes to share price or share price goes to ETF price
- Do this at an international level with ADR's

Example	Price
Calculated Ask	84.03
Calculated Bid	84.0075
ETF Bid	84.04
ETF Ask	84.05

What is the potential profit of this trade?

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HFT AND FLOW

- Pure Arbitrage
  - Fastest always wins
- Deal Flow
  - Orders executed on behalf of another client
  - E*TRADE – guaranteed 2 second execution market
  - Smart Orders
- Example Companies
  - Citadel, market makers, Goldman, JP Morgan, etc.

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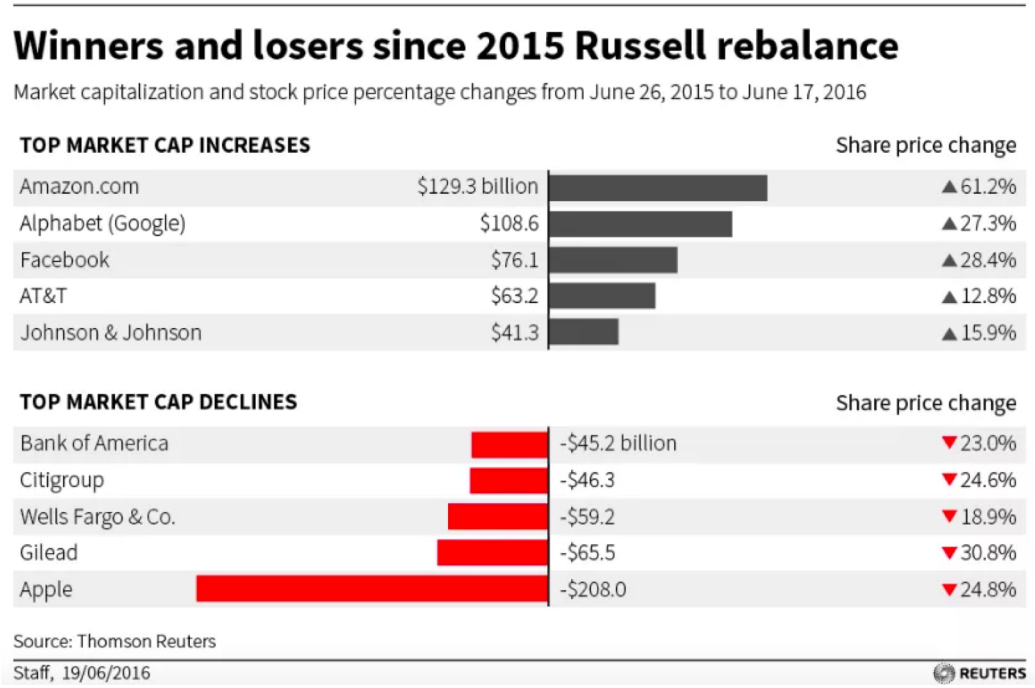
DEAL FLOW: THE RUSSELL REBALANCE

- Bank will trade all of the positions on behalf of FTSE Russell (moves ~20 Billion in a few hours) for a single client
  - Buys up in anticipation of the trade and sells their own shares to the client
  - Massive market moves
- Legalized insider trading and market manipulation due to sheer size of orders
- Goldman actually pays Russell (and the like) for their order flow!



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GENERAL INFORMATION

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APPENDIX: SHARPE RATIO

$$Sharpe = \frac{r_p - r_f}{\sigma_p}$$

$$r_p = portfolio\ return$$

$$r_f = risk\ free\ rate$$

$$\sigma_p = standard\ deviation\ of\ return$$

- Measures risk adjusted performance
  - Risk vs. Reward
- Higher is usually better
- Risk free rate sometimes assumed to be 0
- Usually annualized and volatility taken as standard deviation
  - Monthly: Volatility sampled monthly * sqrt(12)
  - Daily: Volatility sampled daily * sqrt(252)
  - Minutely: Volatility sampled minutely * sqrt(390*252)

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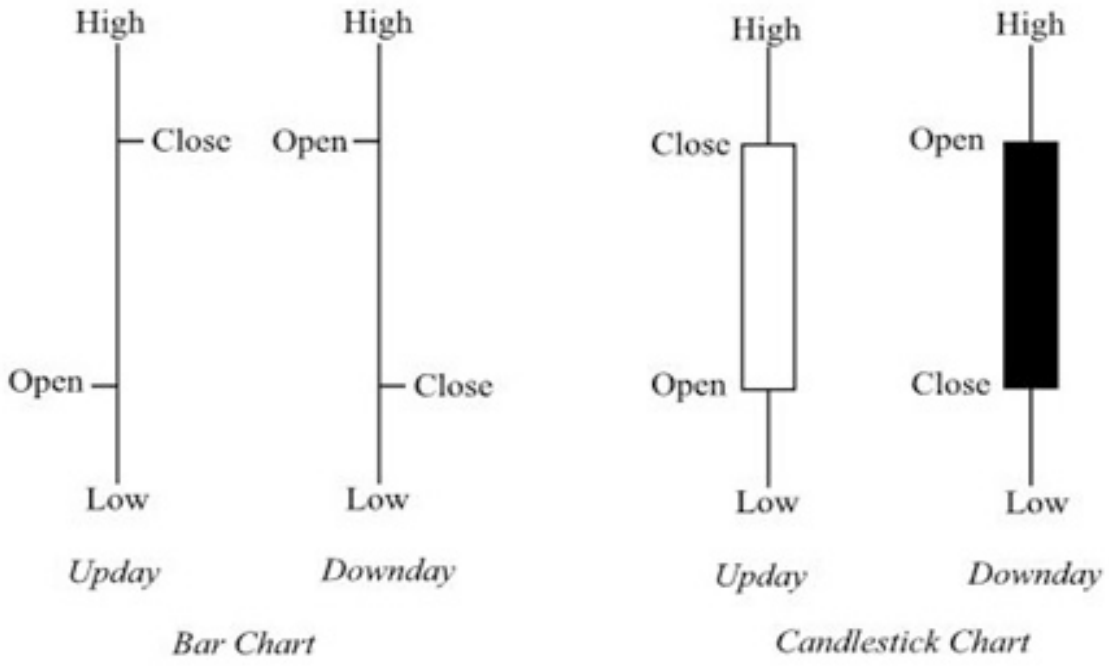
APPENDIX: CANDLESTICK/BAR DATA

- Open – price at start of bar
- High – highest price
- Low – lowest price
- Close – price at end of bar
- Volume – number traded during bar
- Can be on any timescale: seconds to monthly



http://www.financial-spread-betting.com/course/candle-stick-charting.html

APPENDIX: ORDER SIZING

- Average True Range Scaling
- Reduces trade size during times of volatility, Increase during low volatility
- Increases Sharpe Ratio
- Can adjust to size of contract, and/or contract price

$$Initial\ Capital = \$1{,}000$$

$$Trade\ Size = Initial\ Capital \frac{Initial\ Capital}{ATR(10) * Min\ Tick\ Size(\$)}$$

$$True\ Range = \max\left[(high - low), abs\left(high - close_{prev}\right), abs\left(low - close_{prev}\right)\right]$$

$$ATR_t = \frac{ATR_{t-1}(n-1) + True\ Range_t}{n}$$

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APPENDIX: PPC PROFIT PER CONTRACT

$$\frac{r_a}{c * t_s}$$

$$r_a = average\ return$$
$$c = number\ of\ contracts\ traded$$
$$t_s = tick\ size$$

- A measure of profitability, measured in ticks
- A highly liquid stock usually has a tick size of a penny
- If your strategy has more than 2 ticks, it is considered profitable (can escape the bid/ask bounce), if testing on bar data without limit order execution on bar closes
  - You can submit market orders and still make money
    - Assumes liquidity!!!!!

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APPENDIX: CAPM
CAPITAL ASSET PRICING MODEL

$$r_a = r_f + B_a(r_m - r_f)$$
$$r_f = Risk\ Free\ Rate$$
$$B_a = Beta\ of\ Security$$
$$r_m = Expected\ Market\ Return$$
$$r_a = Asset\ Return$$

- Describes the relationship between risk and the expected return
- Investors need to be compensated for time (risk free rate) and risk (beta)

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APPENDIX: DRAWDOWN

- The measure of the largest drop from peak to bottom (in percentage)
  - It is a pain index measure
- Extremely important to measure the duration of the drawdown
  - Do you want to be losing money for years?

$$D(T) = \max_{t \in (0,T)} \{X(t) - X(T)\}$$

$$\text{MDD}(T) = \max_{t \in (0,T)} [\max_{t \in (0,\tau)} \{X(t) - X(\tau)\}]$$

- Where $X = (X(t), t \geq 0)$ is a random process
- Simply put maximum drawdown is:
  - (Peak value before largest drop – lowest value before new high) / Peak value before drop

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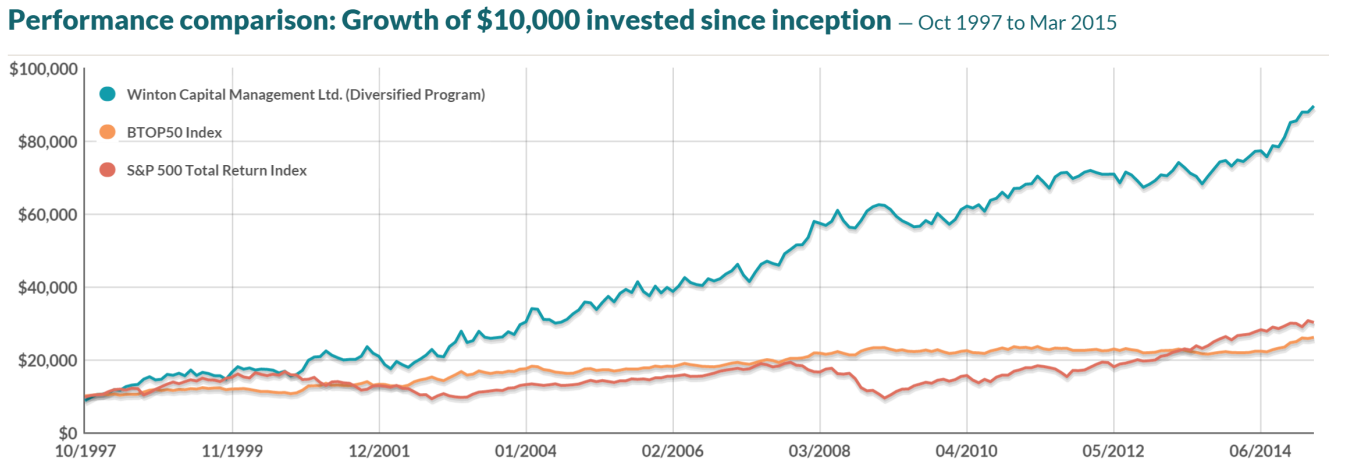
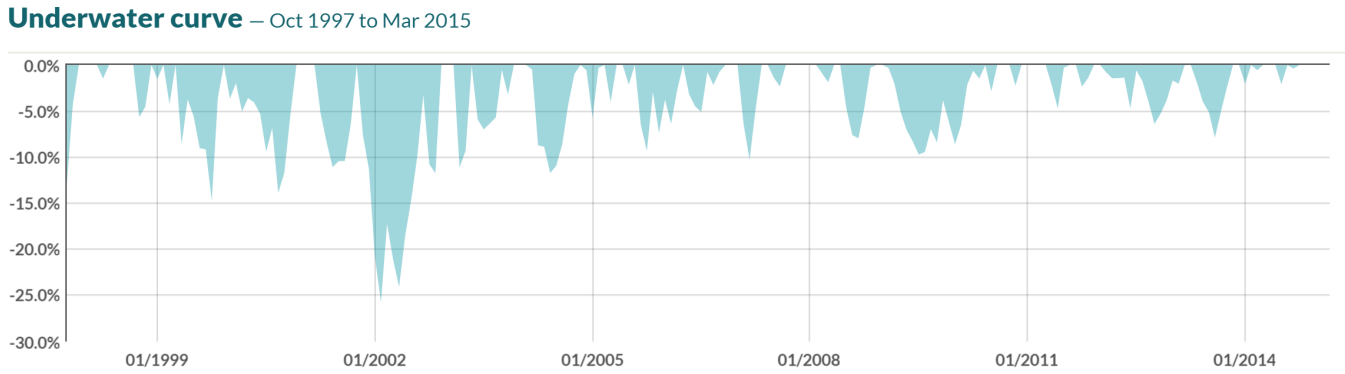
APPENDIX: UNDERWATER CURVE

- Good way to visualize how much of the time you are in a drawdown
- Lets you evaluate how much pain you should be able to handle





http://ctaperformance.com/wntn

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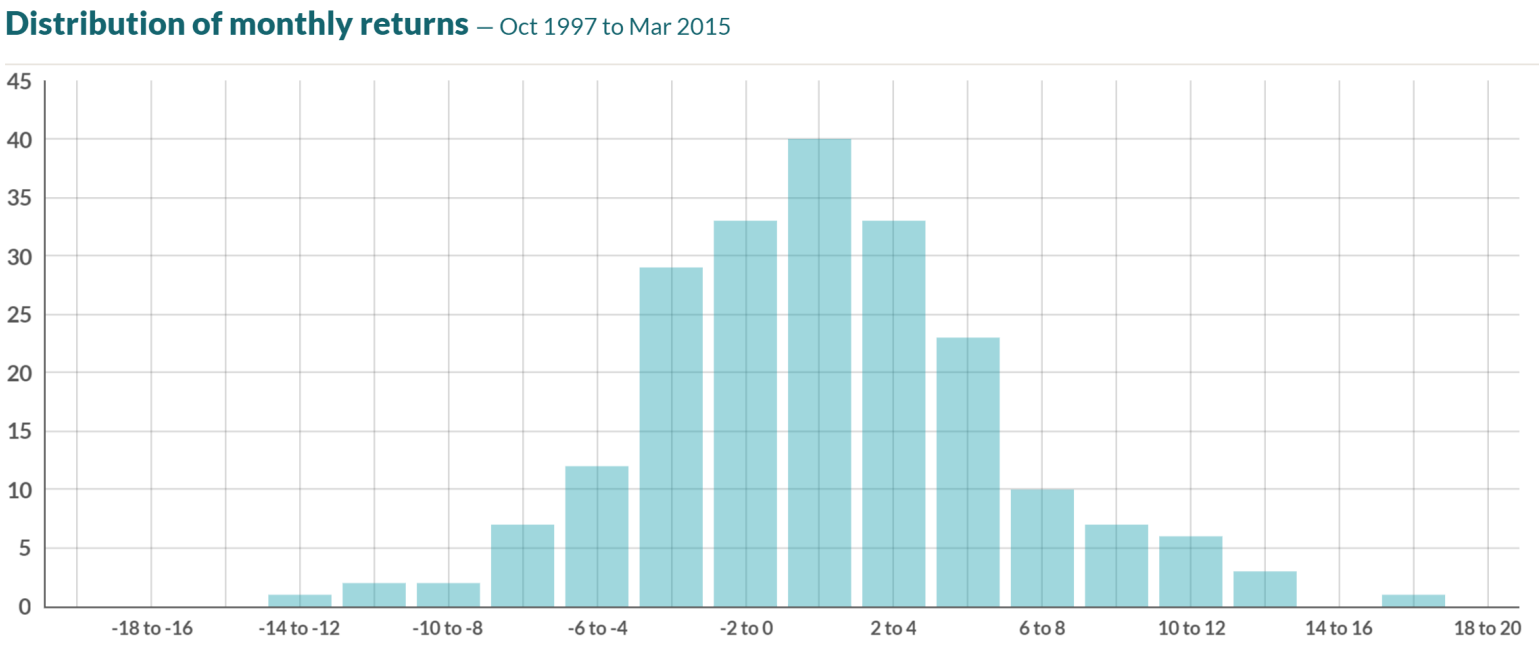
APPENDIX: DISTRIBUTION OF RETURNS



http://ctaperformance.com/wntn

- Generally a histogram of returns
- Look at center, shape, distribution, spread
  - Want positive center, and no major outliers

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APPENDIX: STRATEGY CORRELATION

- Generally you want to make sure that your strategies are not correlated to each other (look at daily returns)
  - You do not want everything to have a bad day at the same time
  - Balanced returns are good
- Uncorrelated strategies tend to yield higher Sharpe ratios when mixed
- Correlated strategies tend to reflect the same alpha
  - These strategies tend to compete with each other
- Negatively correlated strategies can be good
  - Highly negatively correlated strategies can indicate problems with your alpha

Thank you Aaron Rosen for your feedback

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APPENDIX: TRADABLE AUM

- Not all strategies are created equal
- Strategy A might be able to trade $1,000,000 without incurring large slippage but trading $100,000,000 it might incur much more slippage and kill the strategy
  - Market making – your ability to capture the inside bid offer decreases with size
  - High frequency strategies
  - Some momentum strategies
- Sharpe ratios and AUM tradable are usually inversely correlated
  - There are some exceptions
- Note that these numbers are artificial

Thank you Aaron Rosen for your feedback

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