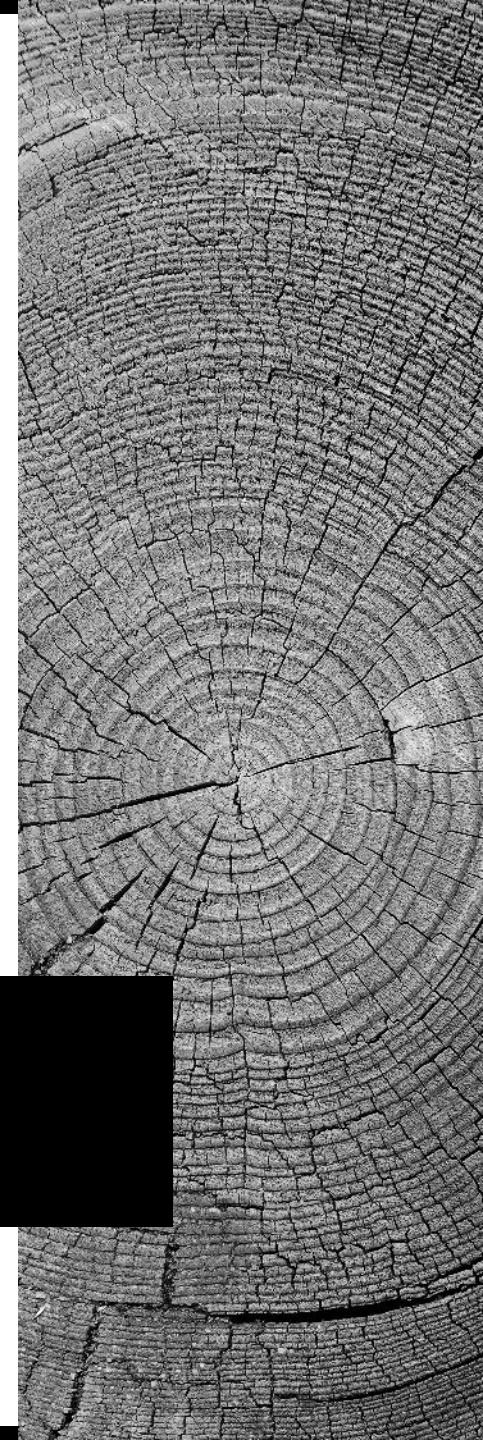


ALGORITHMIC TRADING

*Performance and risk
management*





INTRO

Basic notions

WHAT WILL THE COURSE BE ABOUT?

- Some minimal theory:
 - Finance and market microstructure
 - Statistics
 - Mathematics and computer science
 - Philosophy
- Methodology and developing an idea
- Some simple sample projects

WHO ARE THE MAIN PLAYERS?

- Renaissance Technologies
- AQR Capital
- Acadian Asset Management
- Capula
- PanAgora
- DE Shaw
- Two Sigma
- Citadel Securities

DIFFERENCES FROM REALITY

- We will not do a trading API integration, but will look at how one could be done
- We will not execute orders but we will generate some orders (depending on time)
- We will not do proper backtesting, we will not do exhaustive scenario analysis and we will do minimal hypothesis confidence checks
- We will spend more time on capital allocation



MATHS

*Names, papers and
theorems*

WHEN DID MATHS START INFLUENCING FINANCE

- **Alfred Cowles III:** the first proper econometrist and data gatherer
- **Louis Bachelier:** The Theory of Speculation; Brownian motion, modeling of stochastic processes and asset prices
- **Benoit Mandelbrot:** financial markets are an extreme example of randomness; price changes do not follow the Gaussian distribution; observed distributions have the property that the sum of many instances of a random variable follows the same distributions but with varying scale parameters ==> Fractals in finance researched starting when intraday tick-data was available
- **Harry Markowitz:** The founder of the Modern Portfolio theory
- **William Sharpe:** the first economist-programmer (on a Neumann machine). CAPM (capital asset pricing model – Nobel prize 1990) : a way to value/price a security; the concept of risk-adjusted returns (the measure of performance of a fund manager/stock versus the volatility of its returns; which eventually lead to the creation of the index fund.
- **Eugene Fama:** extensive data collected and proved Mandelbrot's theory that the stock market price action is largely random and suffers from out-of-sample swings, "fat-tails". Further reading: Nassim Taleb – Fooled by Randomness.

BROWNIAN MOTION AND BACHELIER

- What is Brownian motion and why is it relevant Science in Economics?
 - Pattern of motion consisting of random fluctuations in a particle's position inside a fluid, where the fluid is at thermal equilibrium – Robert Brown in 1828 about pollen particle movement in water
 - 1900 Bachelier works out the mathematics of it and applies it to asset pricing
 - 1905 Albert Einstein: modelling of pollen particle movement in relation to water molecule movement
 - 1908 Jean Perrin expanded on this and provided experimental evidence of the existence of atoms and molecules. **Nobel prize**
- Bachelier: "contradictory opinions in regards to [market] fluctuations are so divided that at the same instant buyers believe the market is rising and sellers that it is falling... It seems that the market, that is to say, the totality of speculators, must believe at a given instant neither in a price rise nor in a price fall, since, for each quoted price, there are as many buyers as there are sellers"
- Taking gut instinct out of finance and introducing mathematics

BROWNIAN MOTION AND BACHELIER

- The thesis was translated to English in the 1950s on commission by Paul Samuelson (Nobel prize in 1970 for contributions to all branches of economic theory)
- Also translated at this time: Benoit Mandelbrot's works on options and price modeling
- Samuelson's geometric Brownian motion model:

$$S(t) = S(0) \exp(at + \sigma W(t))$$

Where: $S(t)$ – asset price; $W(t)$ is the Brownian motion; a , σ are constants.

$$a = \alpha - \frac{1}{2} \sigma^2$$

σ – volatility (standard deviation of log returns); α - expected growth rate

CODE BREAK:

1/ Simulation of asset pricing paths with Geometric Brownian Motion and Pareto distribution for volume

2/ Time series simulation processes implemented according to Mandelbrot's description in 'A Multifractal Model of Asset Returns'

3/ Rescaled Range analysis: Edgar E. Peters: "Fractal Market Analysis"

RESCALED RANGE ANALYSIS, HURST EXPONENT

- Rescaled Range analysis : analyze trends in a time series (originally developed by Hurst to predict flooding on the Nile)
- In finance it's used to look for cycles, patterns and trends in stock and bond prices that might repeat or reverse in the future, by determining the persistence or mean-reverting tendencies within that data
- The result of the analysis is the Hurst exponent which is $(0,1)$, where:
 - $H > 0.5$; strong long-term trend
 - $H < 0.5$; trend reversal is likely
- Practically: it is one method to filter out the measure of randomness in a dataset
- So in a real-life scenario: trend-trading. Analyze stock data that shows strong persistence ($H > 0.5$). If $H < 0.5$, pair it with a technical indicator to spot price reversal. Equally: look for $H < 0.5$ paired with a measure of price decline over time to spot an entry point.
- Want to apply it to the entire market? Calculate a MA of the Hurst exponent of the S&P.

MODERN PORTFOLIO THEORY

- Harry Markowitz's idea: in the 1950s dividends were one of the primary reasons for investment in stock markets.
- John Burr Williams' proposal: "The value of a stock should be equal to the present value of the expected dividends it would pay to shareholders over a certain investment horizon"
- Corollary: shouldn't then everyone invest only in the firm that offered the highest dividend yield? (in practice -> madness as it would be incredibly risky)
- Markowitz's idea was then: diversification should be able to nicely reduce the risk and uncertainty. Using the volatility of stock as a proxy for risk, he proved that a "basket" of securities can reduce risk.
- New priorities: should we be concerned then about how individual stocks behave in our portfolio or should we care about how the portfolio in its entirety behaves?
- Nobel Prize in 1990

INDEX FUNDS AND WHY THEY'RE IMPORTANT

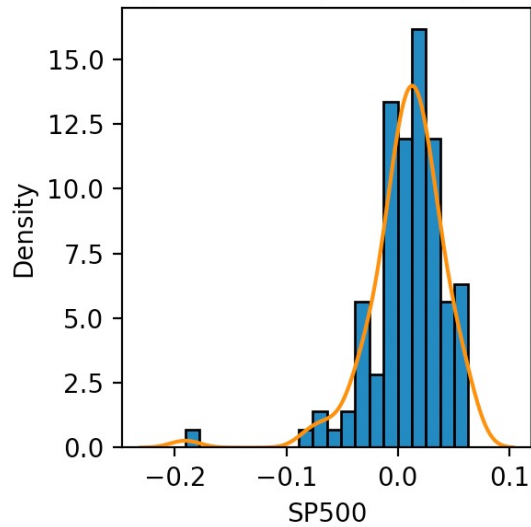
- Big names: Wellington, Wells Fargo, Vanguard
- The biggest catalyst of early democratization of the investment industry
- The first quants
- Precursor of the ETFs, which is still redrawing the investment landscape as of today
- Diversification is a-given
- Low fee structure and the ability to gain exposure to the entire market

SOME FACTS ABOUT RETURNS

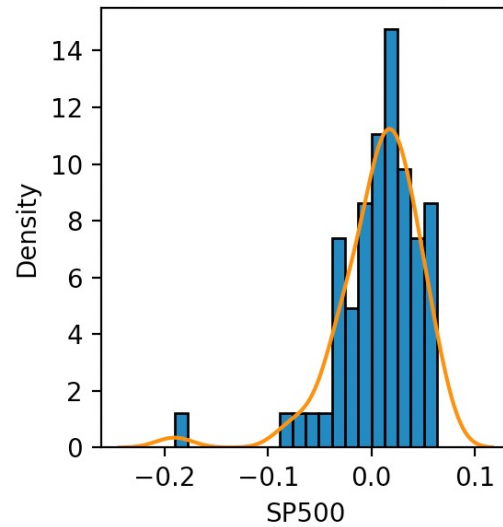
- Entire stock market return distribution vs individual stock return distribution

Density analysis of SnP returns over 1,2,5, 10yr horizons

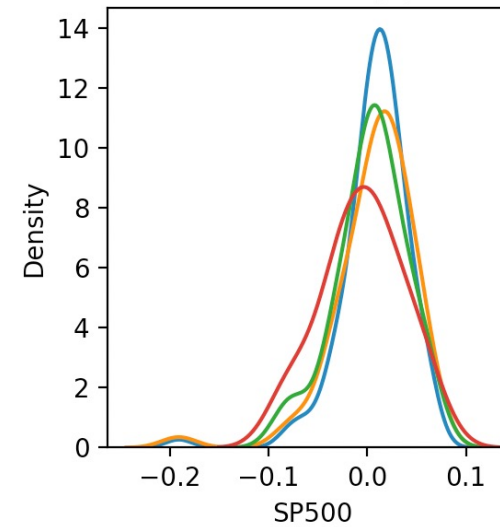
Density Plot of 10yr Monthly Returns



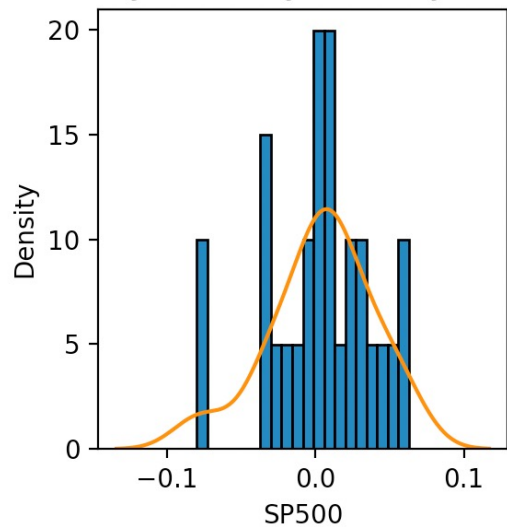
Density Plot of 5yr Monthly Returns



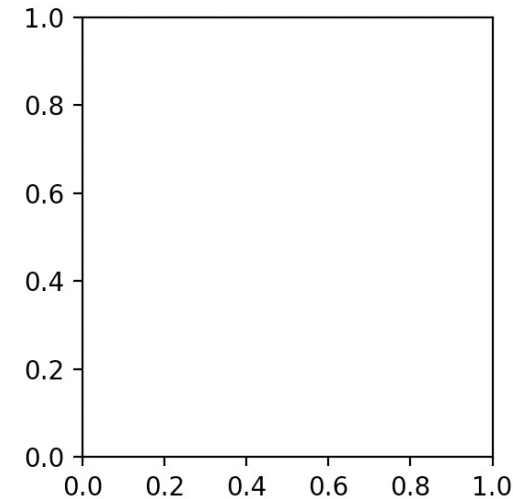
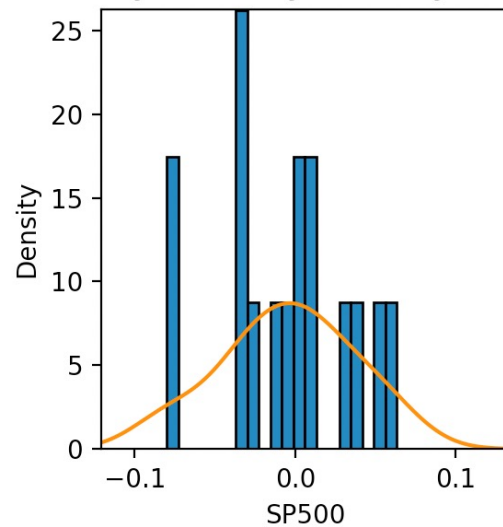
Overlaid density plots.



Density Plot of 2yr Monthly Returns

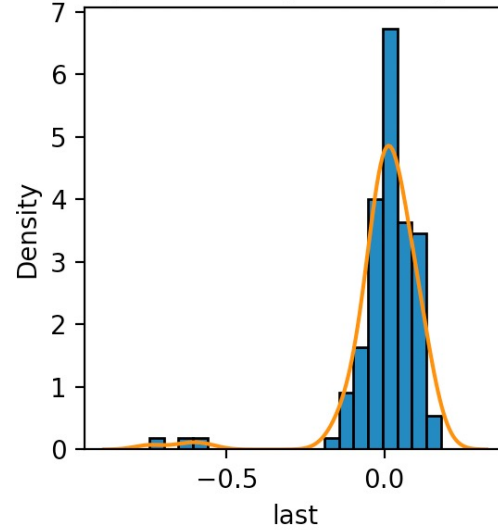


Density Plot of 1yr Monthly Returns

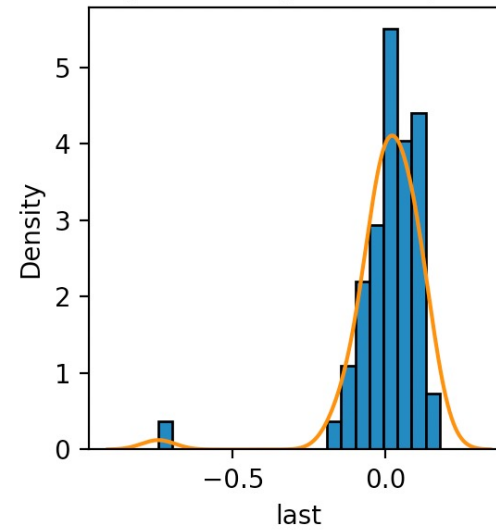


Density analysis of AAPL returns over 1,2,5, 10yr horizons

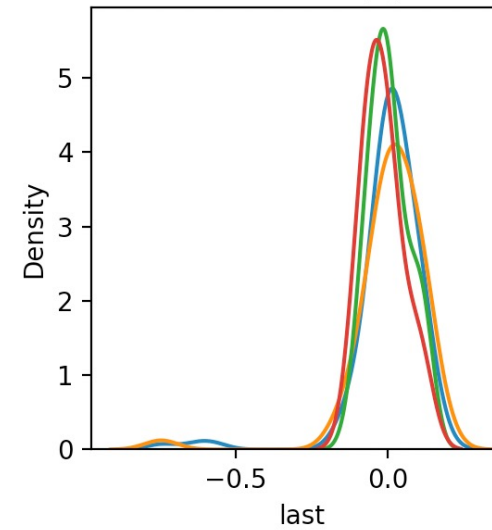
Density Plot of 10yr Monthly Returns



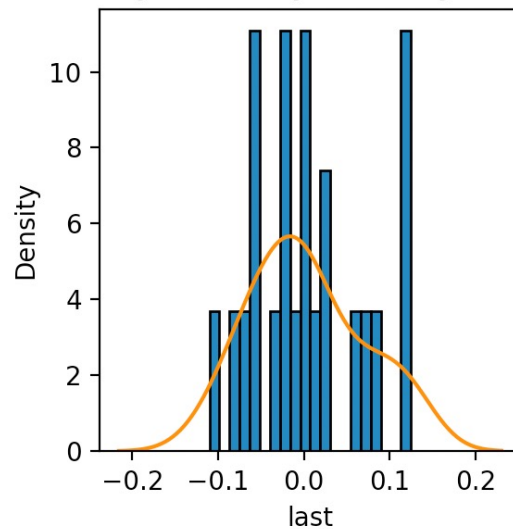
Density Plot of 5yr Monthly Returns



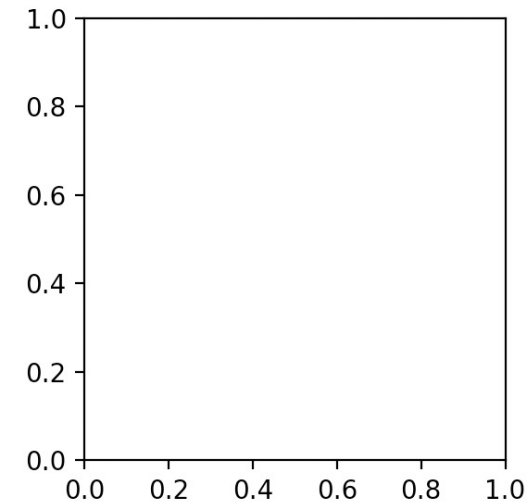
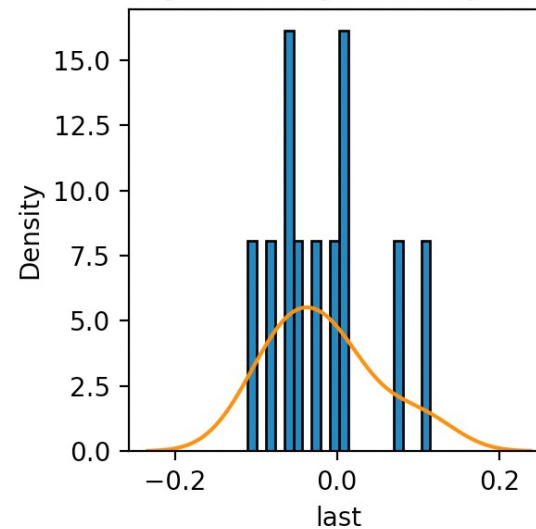
Overlaid density plots.



Density Plot of 2yr Monthly Returns



Density Plot of 1yr Monthly Returns



LET'S GET SOME DATA AND QUICKLY BUILD A PORTFOLIO

- Code break

BUILDING A TRADING STRATEGY

“All models are wrong, but some are useful”

- George Box

IDEATION

Ideas can come from nearly anywhere



WHAT TO CONSIDER?

Step 0

Questions to ask yourself:

- How much time do you have?
- Are you part-time or full time?
- How good a programmer are you?
- Would you like to fully bootstrap the solution?
- What is your starting capital?
- How much can you afford to spend on market data/infrastructure?
- What are your transaction costs?

WHAT TO CONSIDER?

Step 0

Common leverage rules:

- Overnight positions: 2x leverage
- Intraday positions: 4x leverage

Capital availability also determines:

- Directional trades (long or short only) **lowest**
- Dollar-neutral trades (hedging or pir trades) **medium**
- Market-neutral (beta of the portfolio vs index is approx 0) **highest**

QUESTIONS TO ASK ABOUT MARKET DATA?

Step 0.b

What data do you *really* need:

- Historical end of day
- Live intraday
- Historical tick data
- Fundamental data/news?
- Historical fundamental? Analyst forecasts and earnings behaviour, historical?

Is your data source:

- Adjusted for survivorship bias?
- Adjusted for corporate actions?

QUESTIONS TO ASK ABOUT MARKET FOCUS?

Step 0.c

- What asset classes are you comfortable with?
- What markets should you focus on?
- What timespan are you most comfortable with?
- What style are you comfortable with?
- Should you specialize in a few names?

QUESTIONS TO ASK ABOUT MONEY MGMT?

Step 0.d

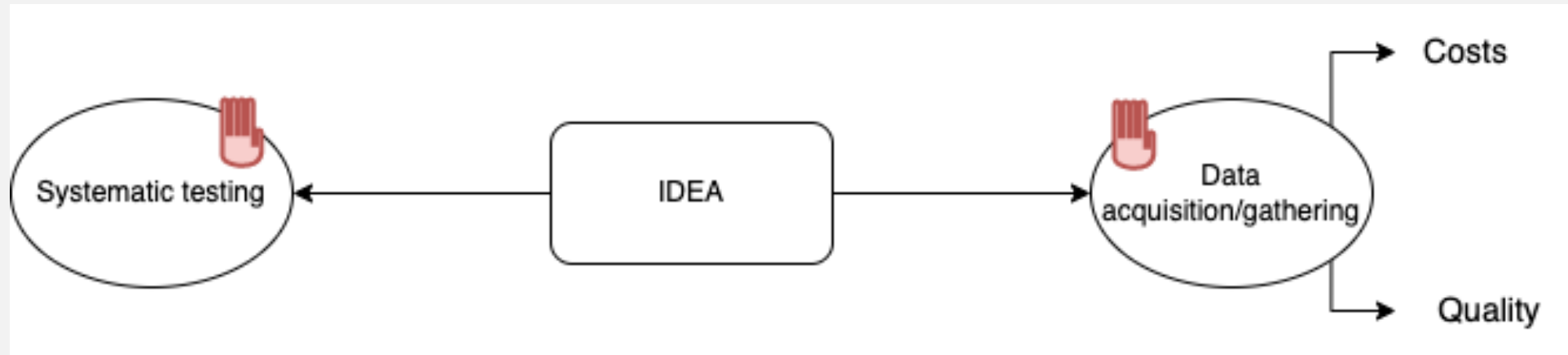
What are your goals? **Long term wealth accumulation?**

Buy- and hold?

How about a strategy with the maximum possible Sharpe Ratio *with the caveat that you need to have access to sufficiently high leverage.*

IDEATION

Ideas can come from nearly anywhere



EFFICIENT MARKETS

What strategy should I take and how do I look for "exploits"

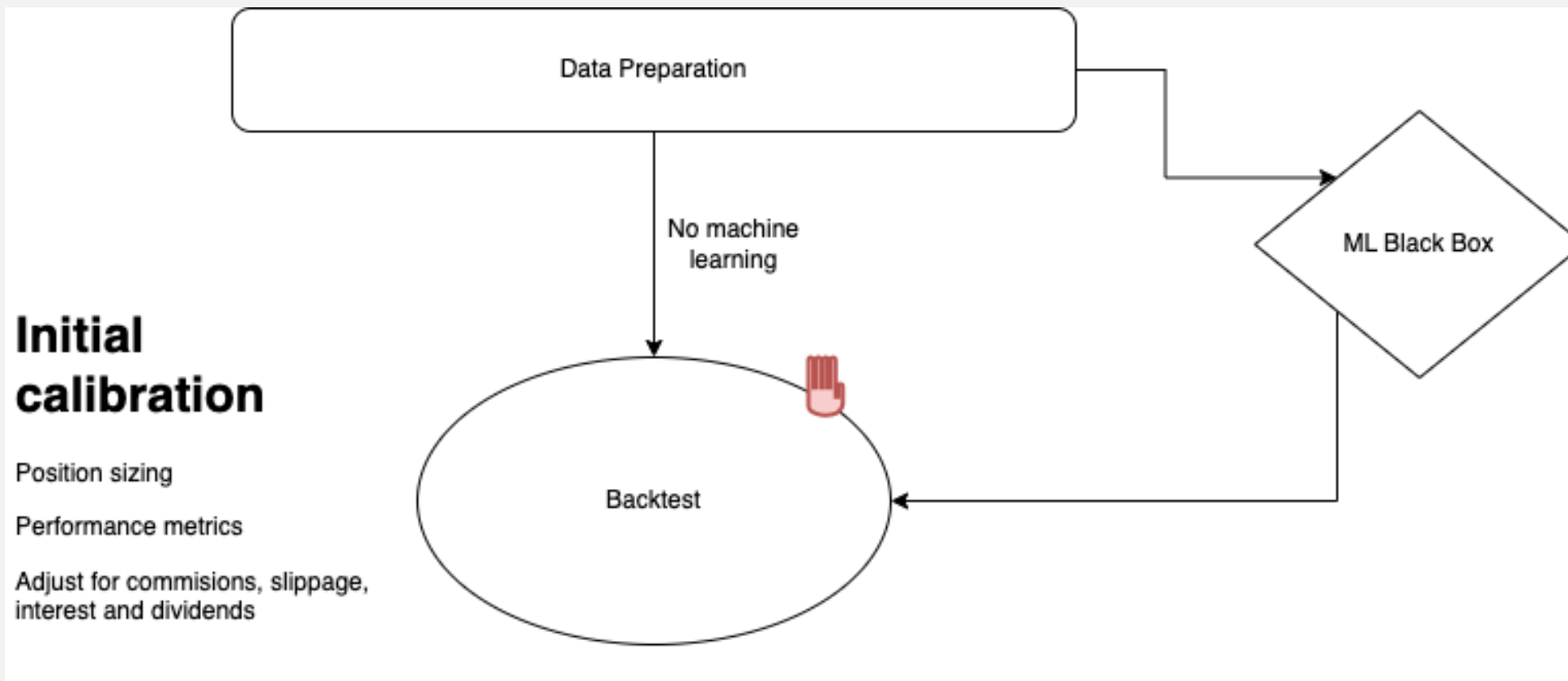
- Are the markets perfectly efficient?
- Eugene F. Fama came to the conclusion in 1970 that markets are "informationally efficient". There are three levels of strength to this affirmation:
 - Weak: stock prices reflect all available information. Past performance is irrelevant for future returns, technical analysis is useless.
 - Semi-strong: all publicly available information is factored into stock prices. Fundamental analysis is useless.
 - Strong: all information, public and private, is factored into prices. The market is perfect, making a profit exceeding that of the market is impossible.
- How do we formulate criticism?
- In reality, the temperate approach is to:
 - Count on price elasticity, i.e. time required for the market to return to fair value
 - Even under efficient markets, random events can happen and are acceptable (black swan events)

THE ASYMMETRY OF RISK

Taleb distribution

- What is asymmetric risk in returns?
- How does it work in practice? In a speculative bubble you enter a position that is likely to rise and less likely to fall, then exit the trade before the rare event happens.
- Unconsciously? Carry trade. Borrow low-yielding currencies and invest in high-yielding currencies. Global events might result in a carry trader needing to pay back a more expensive currency with a less valuable currency.
- Some hedge funds follow this strategy/distribution until they eventually blow up and are left with the management fees.
- How to value a trade keeping this in mind?

DATA AND PREP



BACKTESTING

First steps

- What type of data do you need to test the strategy? Google that. Free databases are available but data quality varies.
 - Most important factor: the data has to be stock split and dividend adjusted. Without that it's unusable. It's also why it's not tenable to stockpile data if you don't intend to work your data
 - Second most important factor: survivorship-bias free data. Otherwise this can distort test results. Not an issue if you use only blue-chip names
- Don't use High and Low prices, use Open and Close, they're less noisy
- Historical prices might not all be from the main exchange. Build a buffer into open and close prices to (+/- 10%)
- Average annualized returns are a tricky to quote as the use of the denominator to calculate the returns is unclear and varies.

BACKTESTING

Some considerations, based on experience

- Sample-size : make sure that you have sufficient amount of data to backtest. Rule of thumb: $252 \times \text{Number of free parameters to calibrate in the model}$. So daily model with 3 parameters, 3 years' worth of data with daily prices.
- Out-of-sample testing: test your model with half your available data, then save the other half for out-of-sample testing. The second half should be the more recent set. The best out-of-sample testing is always paper trading.

BACKTEST

An example how

- An example platform is: <https://www.wealth-lab.com/>

A FEW WORDS ON BENCHMARKS

What do we measure against?

- 1) Long-only strategy returns 10%. Good or bad?
- 2) Long-short dollar-neutral strategy returns 10%. Good or bad?

How do we measure the alpha of 1)? How about 2)?

How about consistency? Does a strategy that returns the same as the market index but is in the black every month (while the index isn't) superior?

A FEW WORDS ON BENCHMARKS

Filtering out unsuitable strategies

- Does it outperform a benchmark?
- High enough Sharpe ratio?
- Does it have a small enough drawdown and short enough drawdown duration?
- Does the strategy work better the longer the lookback duration?
- Does the strategy have its own “niche” that sets it apart from competition from institutional money managers?

A FEW WORDS ON BENCHMARKS

What do we measure against?

Sharpe Ratio

$$\text{Sharpe Ratio} = \frac{\text{Average of Excess Returns}}{\text{Standard Deviation of Excess Returns}}, \text{ where}$$

Excess Returns = Portfolio Returns – Benchmark Returns

NB: This is actually a special case of the Information Ratio, suitable mostly for Dollar-Neutral strategies. There is more to it.

Generally, though, a unified Sharpe ratio is useful to compare different strategies. In reality a high Sharpe ratio means you can leverage better and higher.

A FEW WORDS ON BENCHMARKS

What do we measure against?

Sharpe Ratio rules of thumb:

- A strategy that trades only a few times a year will have a low Sharpe Ratio
- Sharpe Ratio < 1 **not suitable as a strategy**
- **Annualized** Sharpe Ratio > 2 , general monthly profitability
- **Annualized** Sharpe Ratio > 3 , general daily profitability

A FEW WORDS ON BENCHMARKS

What do we measure against?

$$\text{Annualized Sharpe Ratio} = \sqrt{N_T} * \text{Sharpe Ratio Based on } T$$

Meaning

$$\text{Annualized Sharpe Ratio} = \sqrt{12} * \text{monthly Sharpe Ratio}$$

However, if you have a day-trading strategy on NYSE during NYSE market hours, you need

R – average hourly returns

s – standard deviation of the hourly returns

$$\text{Annualized Sharpe Ratio} = \sqrt{1638} * \frac{R}{s}$$

A FEW WORDS ON BENCHMARKS

What do we measure against?

Excel file : calculation example for long only and long-short market neutral strategies

Long only : not too much to explain

Long-short market neutral : short equal dollar amount of SPY as a hedge.

TREYNOR RATIO

Another way of calculating Risk-adjusted Returns

$$\text{Treynor Ratio} = \frac{R_P - R_f}{\beta_P}, \text{ where}$$

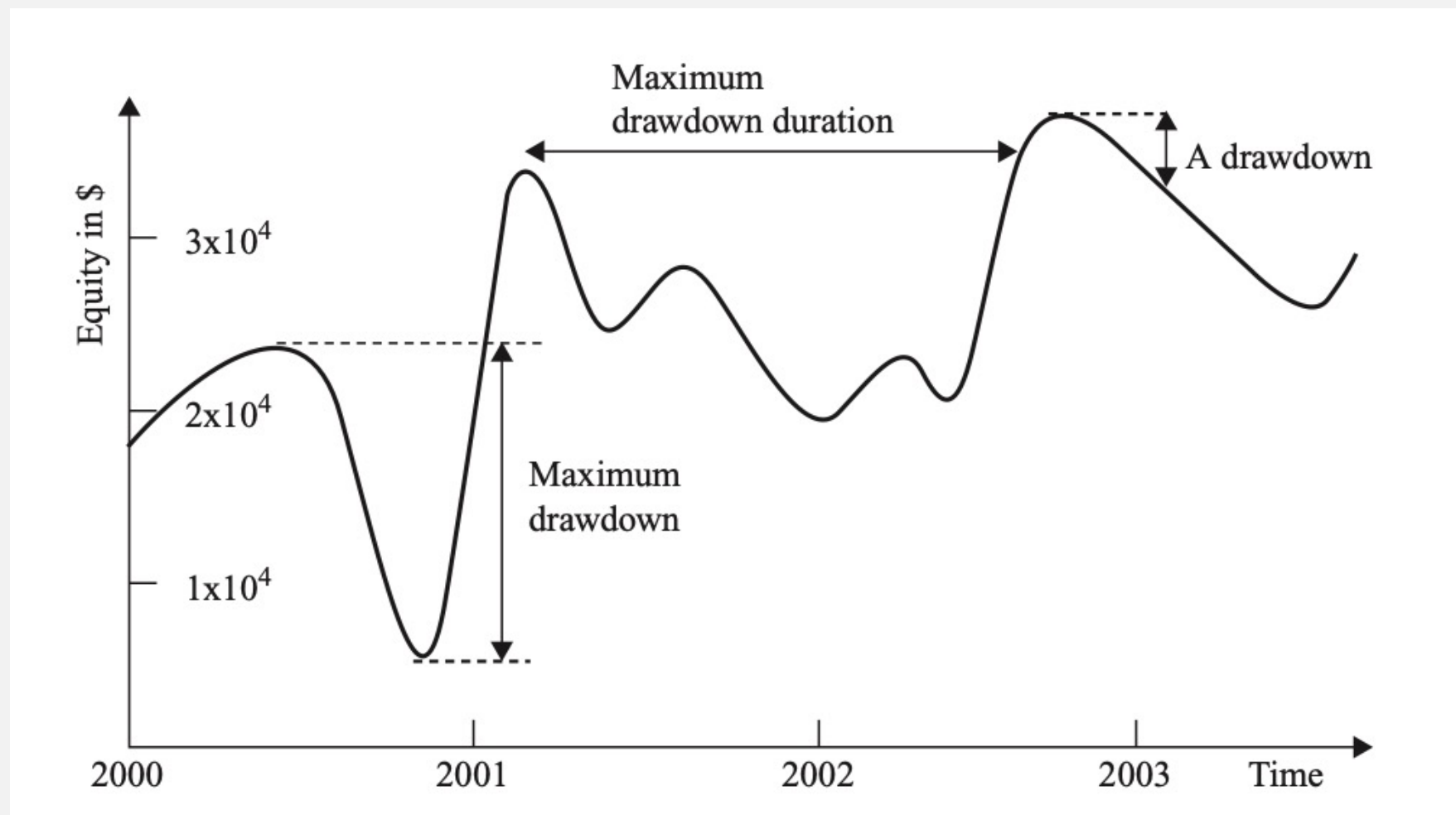
R_P – return of the investment portfolio,

R_F – risk – free rate of return,

β_P – beta of the portfolio, sensitivity of the portfolio's return to market volatility

ABOUT DRAWDOWN

What is drawdown?



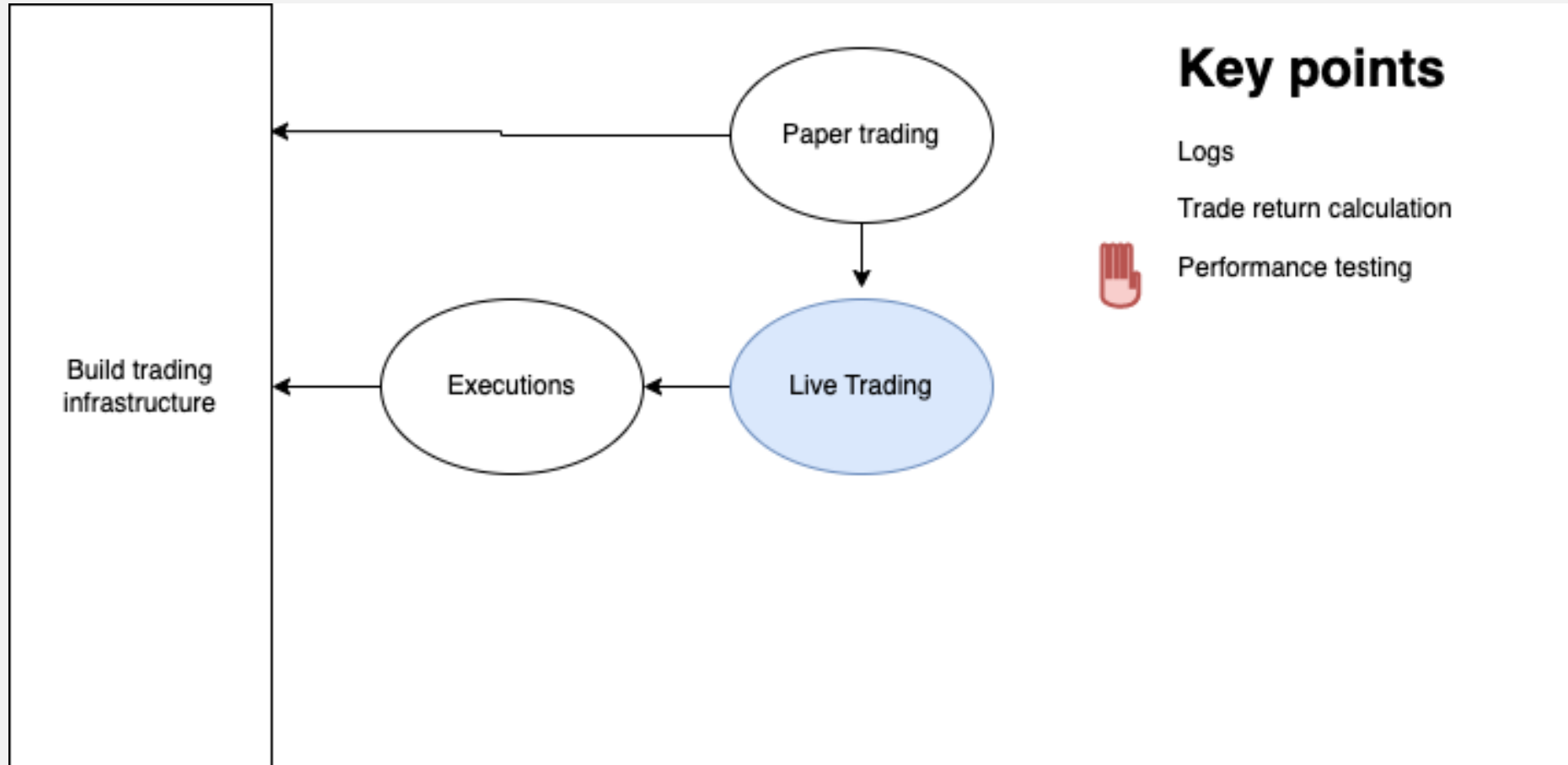
BENCHMARKS

- CODE BREAK

RANDOMIZATION AND ROBUSTNESS

Randomization and Robustness testing

GOLIVE



PORTFOLIO CONSTRUCTION

Cash, Position sizing and value at risk

CASH POSITION SIZING

Should you keep a cash position as part of your portfolio?

Professional money managers

- Index and mutual funds:
 - 5% baseline
 - 5-8% in optimistic market conditions
 - 10% or more in pessimistic market conditions
- ETFs: 0% or as close to 0% as possible
- Questions to ask:
 - What are you investing for?
 - Is there an emergency fund somewhere else?

Private portfolios

- Depends on risk profile fundamentally
- Empirical evidence suggests 5-15% as max risk-return profile
- If you combine cash with “safe-haven bonds”, you could potentially go higher

CASH POSITION SIZING

- Berkshire: \$122 billion in 2019 (similar now), they would go years accumulating cash without investing it
- Capgemini research: also in 2019, average cash size at wealth managers for portfolios above \$1 million was 28%.
- "Dry powder" for discounted assets.
- Buffer for margin calls
- If a portfolio management system is good enough, you won't need to sell assets/securities during a downturn but will have cash to cover the downturn
- Example: 3% cash withdrawal rate on a \$500,000 portfolio of 2,8% yield bonds? 10% cash holdings means you don't need to sell bonds even if the face value tanks
- Inflation hedge if it's in the right currency

SECURITIES POSITION SIZING

How much of my portfolio should I invest in how many stocks?

- BY FAR the most important aspect of a trading strategy (even more relevant in day trading and FX)
- All returns at a portfolio level depends on position sizing. Two managers of identical portfolios can generate completely different returns based purely on sizing.
- Generally speaking, it depends on the individual risk tolerance and account size
- Even the most careful position sizing and stop loss placement won't save you from gapping price action
- Martingale system : you statistically can't lose all the time, so double-down on successive bets. (personal opinion: don't)
- Maximum VaR method

MAXIMUM VAR METHOD

- Determine the number that you're willing to lose from your capital, in case you're wrong on a trade, two trades, three trades, x trades

Scenario: you have 1 Mill. on your account. How much are you willing to risk?

MAXIMUM VAR METHOD

- Rule of thumb: risk 1-2% of your total equity on **total** open positions.
- Reality: depends on trading profile, risk tolerance and account size. Math + Psychology
- "What losses can I stomach?"
- For some 1% is enough, for others 5% is fine.
- Number of stocks to trade means your cumulative VaR should be split among them

PLACING STOP LOSSES

- After determining maximum VaR according to the criteria above, how do you determine the stop loss?
- Maximum VaR: 50,000. You want to buy 100 stocks of X, does that mean 500 max potential loss per stock?
- Price action?
- If the market approaches your stop levels too often, you are probably entering at wrong levels

PLACING STOP LOSSES

- 4 basic methods:
 - Fixed value stop
 - % stop
 - Stop at a technical level
 - Volatility-based stop

Whatever method you'll use, the most important thing to consider is filtering out the price action noise, failure to do this is a very costly mistake.

STOP AT A TECHNICAL LEVEL



VOLATILITY-BASED STOP

w/ the ATR indicator

- ATR shows the average “normal” movement of stock



PLACING STOP LOSSES

- Also essential: the timeframe of the stop and the investment timeframe needs to be in synch.
- Don't forget trailing stops and Risk-reward adjusted stops (i.e.: once risk is earned from potential reward, move the stop up)

DETERMINING ORDER VOLUMES

- Determining Value at Risk: **done**
- Setting Stop orders : **done**
- Then:

$$\text{Order Volume (lots)} = \frac{\text{Maximum VaR}}{\text{Maximum Risk per lot}}$$

- However: Maximum Risk per lot is dependent on the investment horizon

EXAMPLES

- Account Balance: 30,000 USD

Scenario 1: EURUSD pairs, daily chart

- $VaR = AB * 1\% = 300 \text{ USD}$
- Stop gap, in case of a 10,000 USD position = 20 pips = 20 USD
- $Lotsize = 300/20 = 15$
- Hence, we can open 15 positions of 10,000 USD each for a total exposure of 150,000 USD

Scenario 2: DAX index, hourly graph

- Account Balance: 800,000 USD
- $VaR = AB * 4\% = 32,000 \text{ USD}$
- Stop gap, 100 Dax index points, 25 EUR each point, 2500 EUR
- $Lotsize = 32,000 / 2500 = 12,8 \text{ lots}$. Let's call it 12.
- Meaning we can build exposure worth 12 lots of DAX, that's one future or 2 DAX options.

WHAT IF I WANT TO ALLOCATE 100% OF MY CAPITAL

Or... I have a long term outlook

	Allocated value (USD)	Stock	Buy price	Qty	Buy Value (USD)	Stop price	VaR	Risk % (USD)
Slice 1	200000	Tesla	160	1250	200000	77,5	103125	51,56%
Slice 2	200000	Apple	148	1351	199948	135	17563	8,78%
Slice 3	200000	Siemens	125	1428	199920	119	9596,16	4,80%
Slice 4	200000	OTP	10000	6666	199980	7900	41995,8	21,00%
Total	800000						172279,96	21,54%

OTHER METHODS

- CPPI & TIPP
- Volatility Targeting
- Kelly Criterion & Optimal F
- Martingale

OPTIMAL CAPITAL ALLOCATION AND LEVERAGE

- Dr. Edward Thorp, deduced the following formula, used in finance and betting

Optimal fractions of your equity that you should allocate to each position or strategy :

$$f_i = \frac{m_i}{s_i^2}, \text{ where}$$

m_i is the mean return of strategy i ;

s_i is the standard deviation of the returns of strategy i

- Optimal leverage

$$\text{Optimal leverage} = \frac{\text{Annual Excess Return}}{\text{StDev}^2}$$

- Further thought experiment... Calculate the maximum levered growth rate and unlevered growth rate

$$g = \text{MeanAnnualReturn} - \frac{\text{StDev}^2}{2}$$

EXAMPLE TRADING STRATEGIES

Source of inspiration

- Darvas Boxes
 - General idea: buy growth sectors, pick stocks that are at their 52-week high. Buy at second breakout
 - Market we trade on: stock market, daily time resolution
 - Trade only on uptrend or downtrend
 - 200-day MA is the trend identifier line
 - Entry conditions:
 - Long: bullish trend, 52-w high, second breakout where the second breakout is within the 50% Fibonacci retracement vs the first breakout
 - Short: bearish trend, 52-w minimum, followed by an upward correction within 50% of the first down-wave, sell at second minimum.
 - Technical levels allow for a 3x R2R, risk to reward ratio
 - Exit conditions:
 - 3x risk ratio
 - Trailing stop
 - Whichever of the above is hit first

EXAMPLE TRADING STRATEGIES

Trendline-breaking strategy

- Market: stock, daily resolution, multi-day holding pattern
- Trade only in uptrend or downtrend
- Trend-identification: trendline on price action pointing the same direction as 200 day MA
- Bullish trend:
 - Overarching minimum 18 month downtrend broken by price action
 - Price action over 200 day MA
- Bearish trend:
 - Overarching minimum 12 month uptrend broken by price action
 - Price action below 200 day MA
- Entry conditions:
 - Long: uptrending price action breaks overarching downtrend formed by at least two discernible bottoms
 - Short: downtrending price action breaks overarching uptrend formed by at least two discernible tops
 - Enter after breakout + confirmation condition, at market
 - Stop order: based on 3xATR on previous technical level
 - As the price action moves in your direction, move Stop up

EXAMPLE TRADING STRATEGIES

Trendline-breaking strategy

- Exit conditions:
 - Take profit: 3x risk ratio, as long as technical levels allow for that headroom

THANK YOU

HOMEWORK

- Build an equal-weight portfolio out of 3 stocks, calculate stop levels based on the minimum gap between price action to the 50-day moving average, based on the last 6 month's data. Calculate value at risk per position, value at risk for the portfolio. What leverage (optimal) can you take on a portfolio of 100k USD?
- You have 3 stocks at your disposal and their data for the last 10 years. Calculate the beta of the portfolio and the stocks based on the first 5 years worth of data. Optimise the position weights to fit a conservative risk profile. Then optimise the portfolio holding weights for an aggressive risk profile. What annual return would each earn for the remaining 5 years of your data?
- You have 3 stocks at your disposal and their daily data for the last 10 years. Build an equal weight long-only portfolio. Calculate the Sharpe and Treynor ratios of your portfolio. Calculate the individual mean returns, standard deviation of said returns and determine the optimal allocation of funds (100k USD) between the positions while maintaining a reasonably low sensitivity to market volatility (beta). What's reasonable is up to you😊
- Build a portfolio out of 30 stocks, based on 4 segments included in the SnP, by size of market capitalization. Allocate 1000000 USD to that portfolio, equal weight, within each sector. The sector weights should mirror the Snp500 logic.