INTRO TO PORTFOLIO RISK MANAGEMENT IN PYTHON

Estimating Tail Risk

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Estimating Tail Risk

Tail risk is the risk of extreme investment outcomes, most notably on the negative side of a distribution.

- Historical Drawdown
- Value at Risk
- Conditional Value at Risk
- Monte-Carlo Simulation

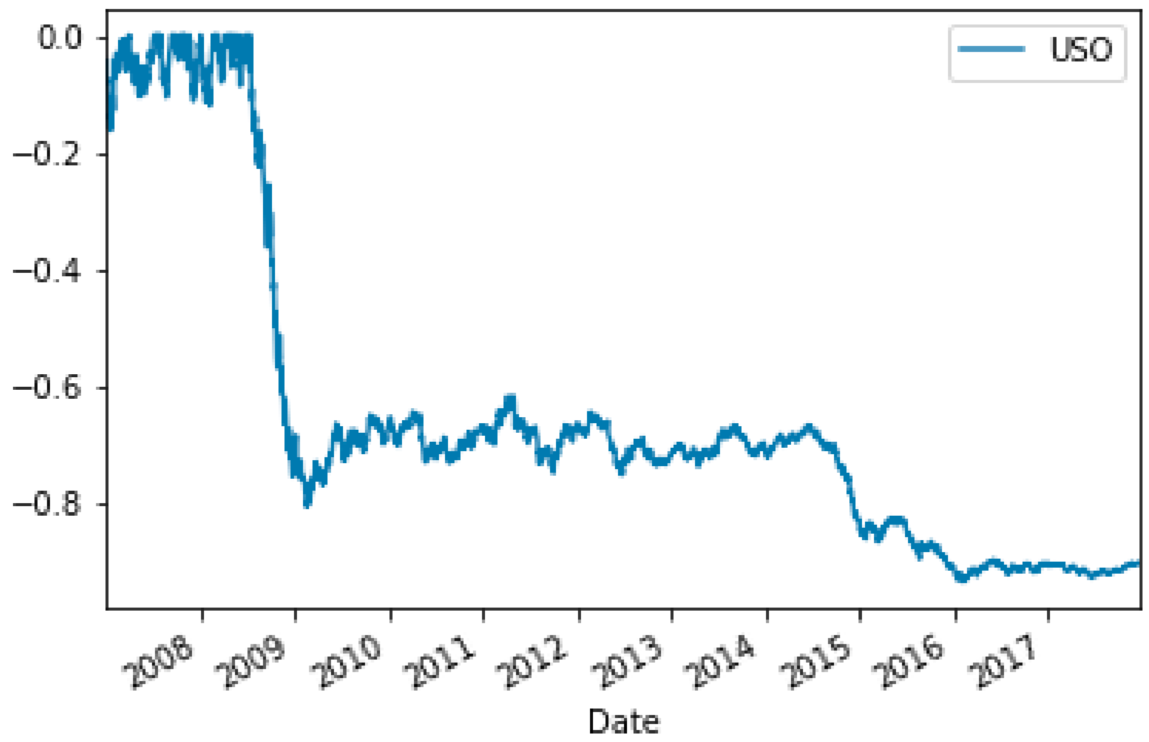
Historical Drawdown

Drawdown is the percentage loss from the highest cumulative historical point.

$$\text{Drawdown} = \frac{r_t}{RM} - 1$$

- r_t: Cumulative return at time t
- RM: Running maximum

HISTORICAL DRAWDOWN OF THE USO OIL ETF



Historical Drawdown in Python

Assuming `cum_rets` is an np.array of cumulative returns over time

```
In [1]: running_max = np.maximum.accumulate(cum_rets)
In [2]: running_max[running_max < 1] = 1
In [3]: drawdown = (cum_rets)/running_max - 1
In [4]: drawdown
Out [4]:
        Date          Return
        2007-01-03     -0.042636
        2007-01-04     -0.081589
        2007-01-05     -0.073062
```

Historical Value at Risk

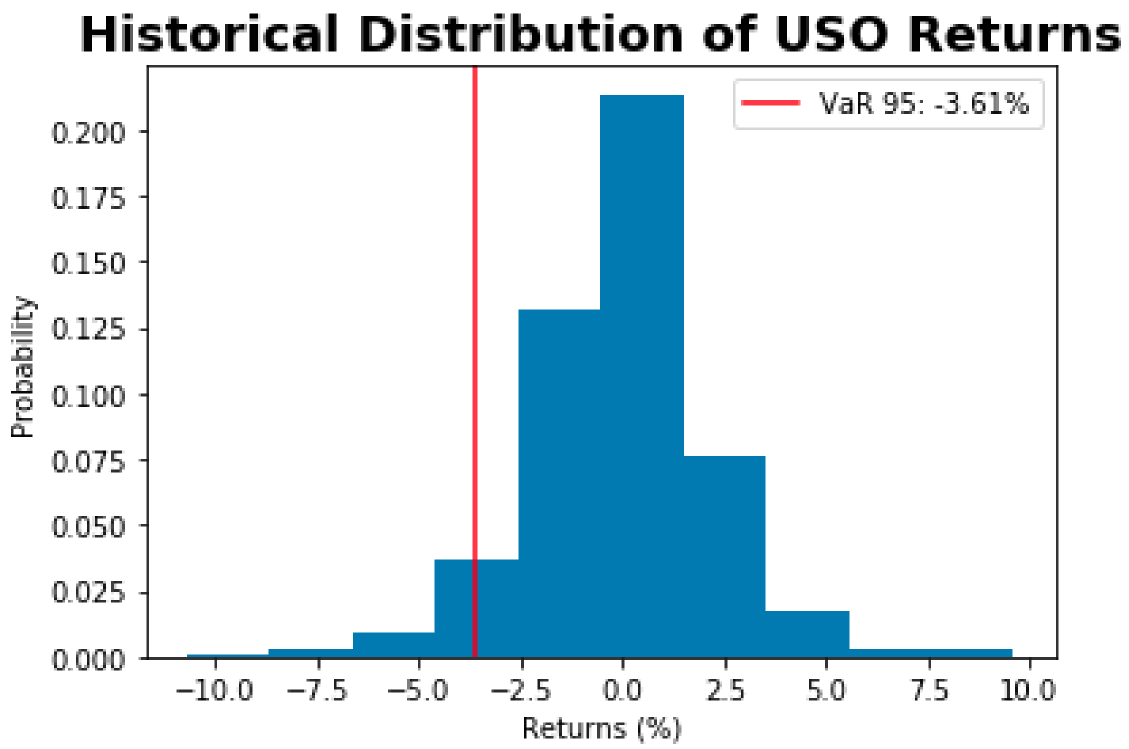
Value at Risk, or VaR, is a threshold with a given confidence level that losses will not (or more accurately, will not historically) exceed a certain level.

VaR is commonly quoted with quantiles such as 95, 99, and 99.9.

Example:

VaR(95) = -2.3%

95% certain that **losses will not exceed** -2.3% in a given day based on historical values.



Historical Value at Risk in Python

```
In [1]: var_level = 95
In [2]: var_95 = np.percentile(StockReturns, 100 - var_level)
In [3]: var_95
Out [3]: -.023
```

Historical Expected Shortfall

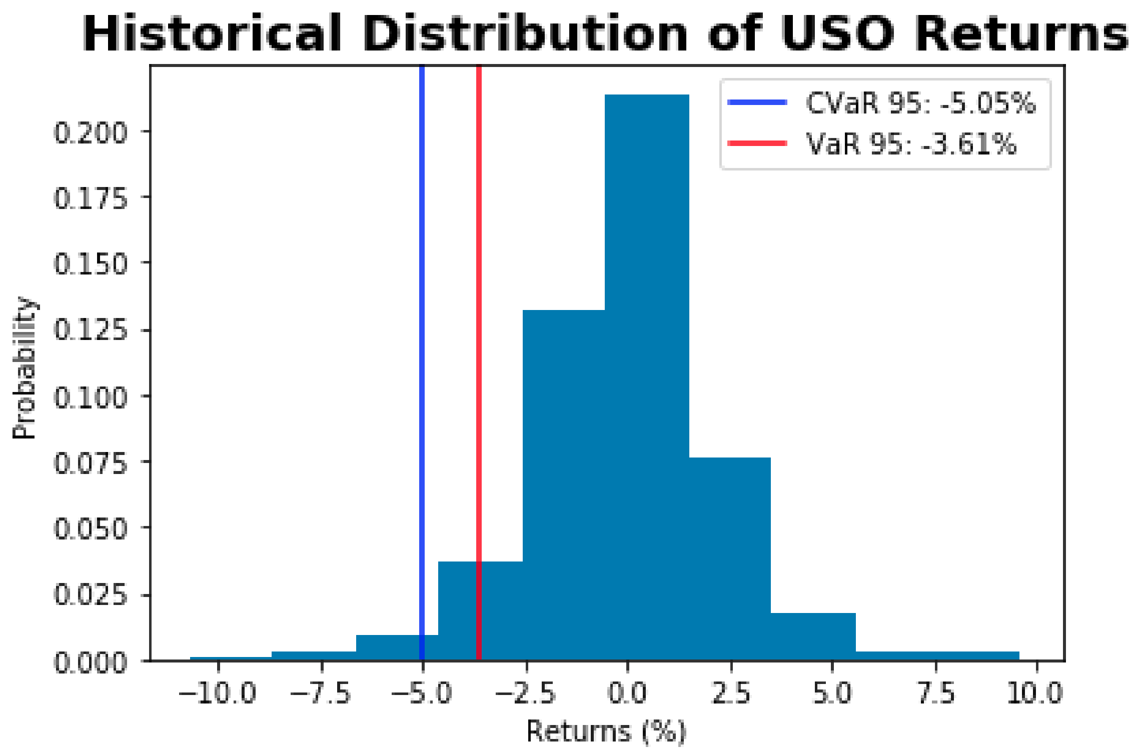
Conditional Value at Risk, or CVaR, is an estimate of expected losses sustained in the worst 1 - x% of scenarios.

CVaR is commonly quoted with quantiles such as 95, 99, and 99.9.

Example:

CVaR(95) = -2.5%

In the worst 5% of cases, **losses were on average exceed** -2.5% historically.



Historical Expected Shortfall in Python

Assuming you have an object `StockReturns` which is a time series of stock returns.

To calculate historical CVaR(95):

```
In [1]: var_level = 95
In [2]: var_95 = np.percentile(StockReturns, 100 - var_level)
In [3]: cvar_95 = StockReturns[StockReturns <= var_95].mean()
In [3]: cvar_95
Out [3]: -.025
```

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Let's practice!

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VaR Extensions

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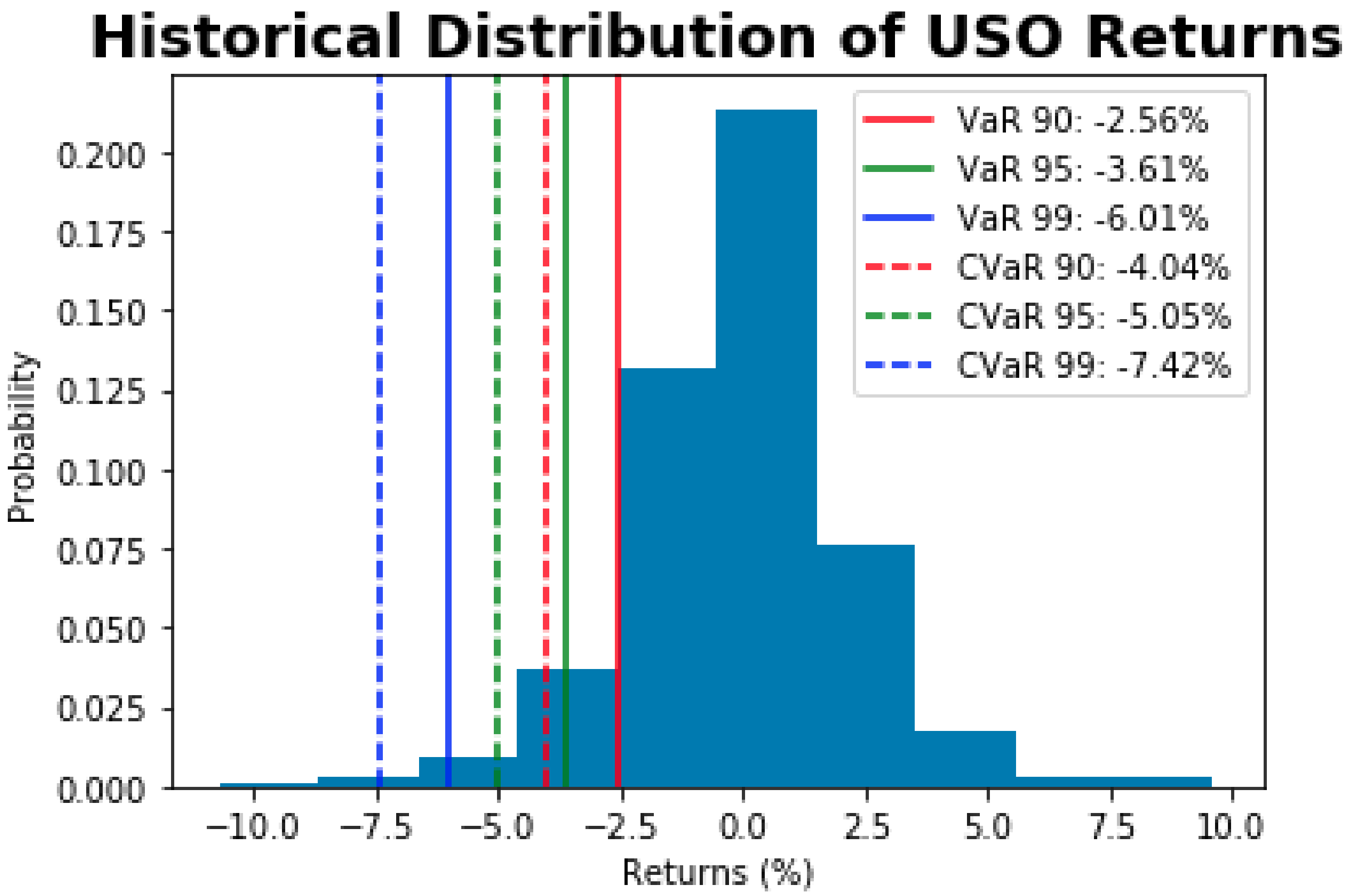
VaR Quantiles



Empirical Assumptions

Empirical Historical values are those that have *actually occurred.*

How do you simulate the probability of a value that has never occured historically before?

Sample from a probability distribution

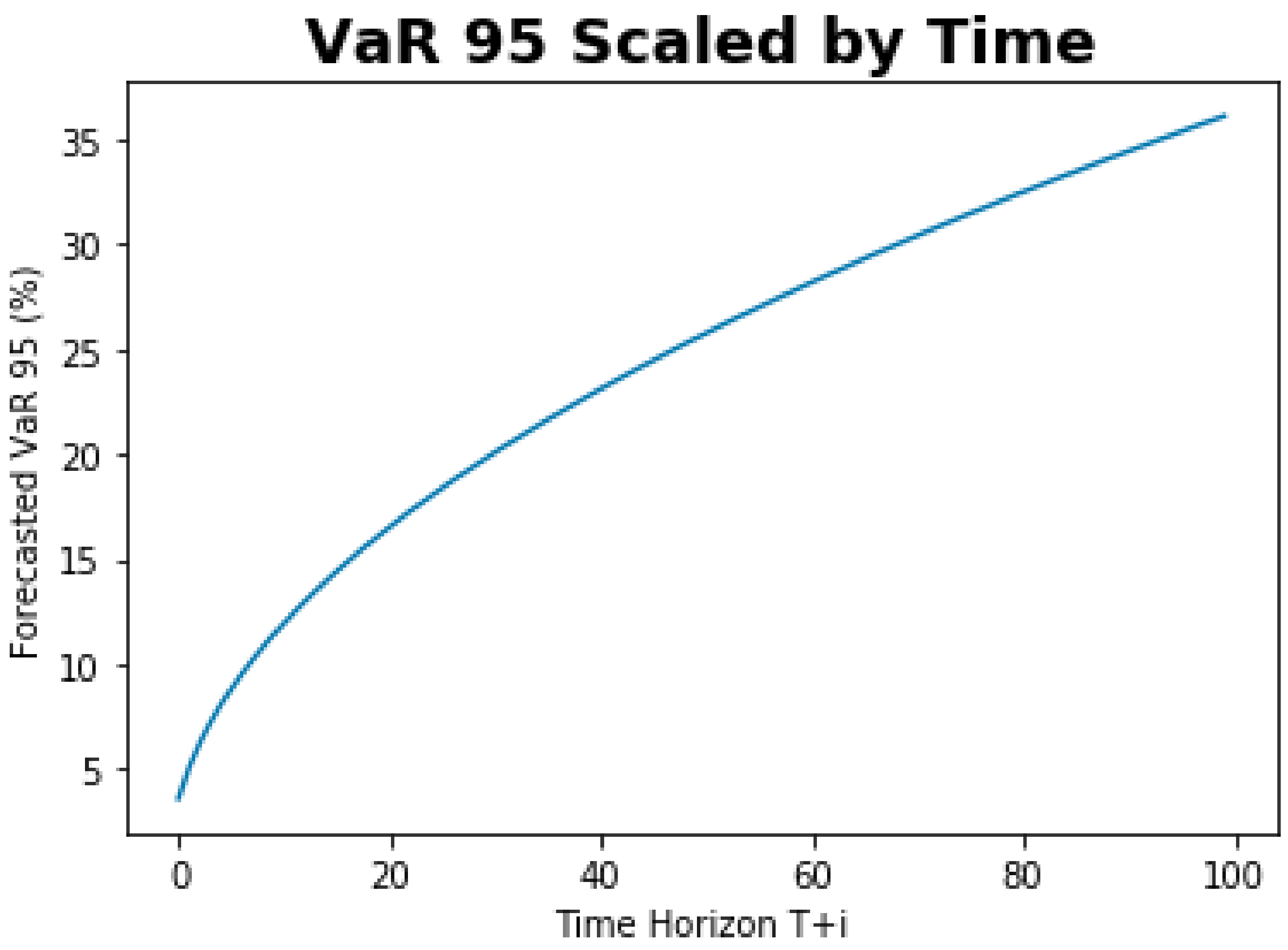
Parametric VaR in Python

Assuming you have an object `StockReturns` which is a time series of stock returns.

To calculate parametric VaR(95):

```
In [1]: mu = np.mean(StockReturns)
In [2]: std = np.std(StockReturns)
In [3]: confidence_level = 0.05
In [4]: VaR = norm.ppf(confidence_level, mu, std)
In [5]: VaR
Out [5]: -0.0235
```

Scaling Risk



Scaling Risk in Python

Assuming you have a one-day estimate of VaR(95) `var_95`.

To estimate 5-day VaR(95):

```
In [1]: forecast_days = 5
In [2]: forecast_var95_5day = var_95*np.sqrt(forecast_days)
In [3]: forecast_var95_5day
Out [3]: -0.0525
```

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Random Walks

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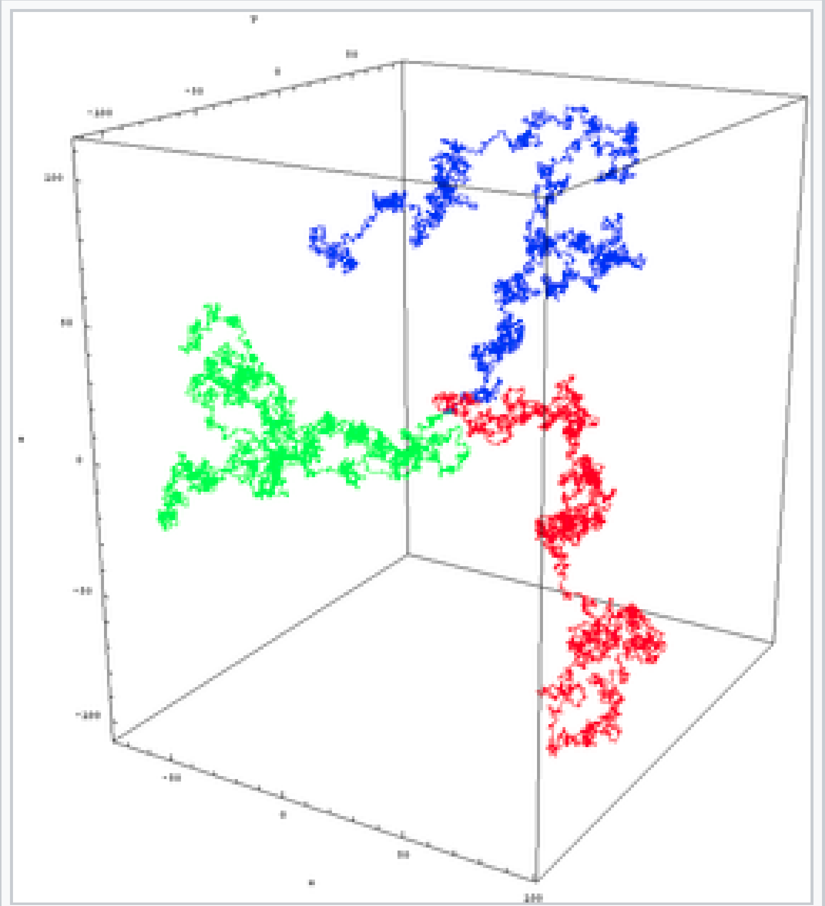
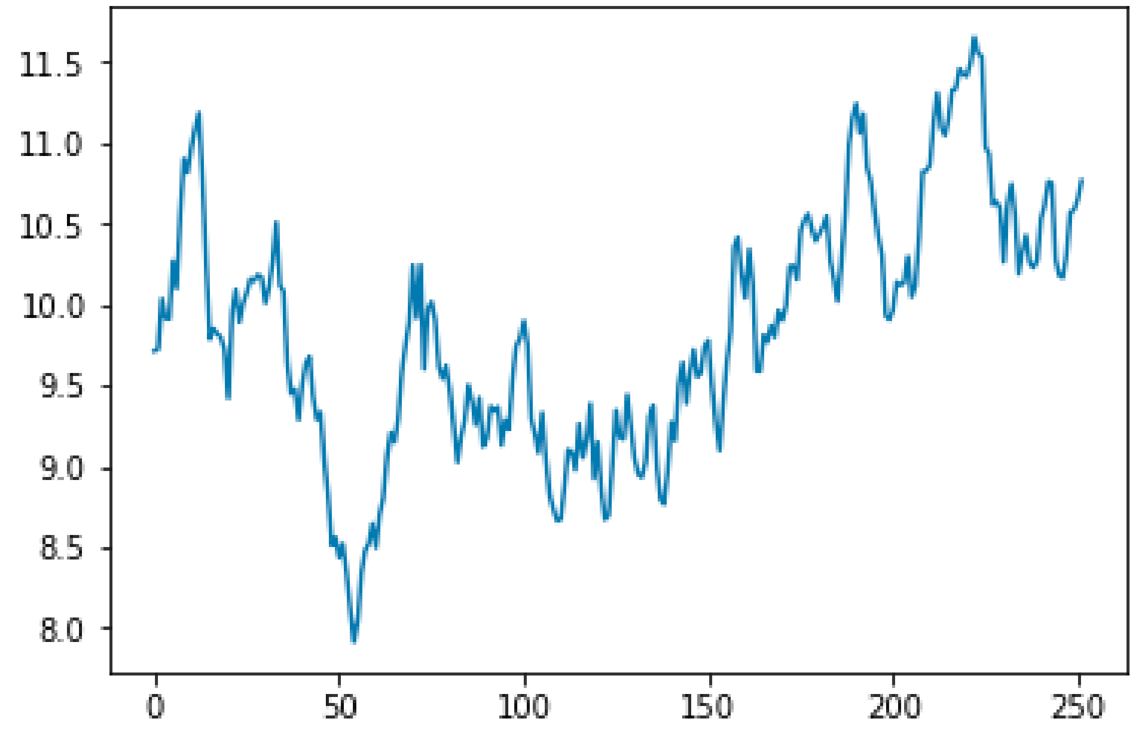
Random Walks



Three random walks in three dimensions

Most often, random walks in finance are rather simple compared to physics:



Random Walks in Python

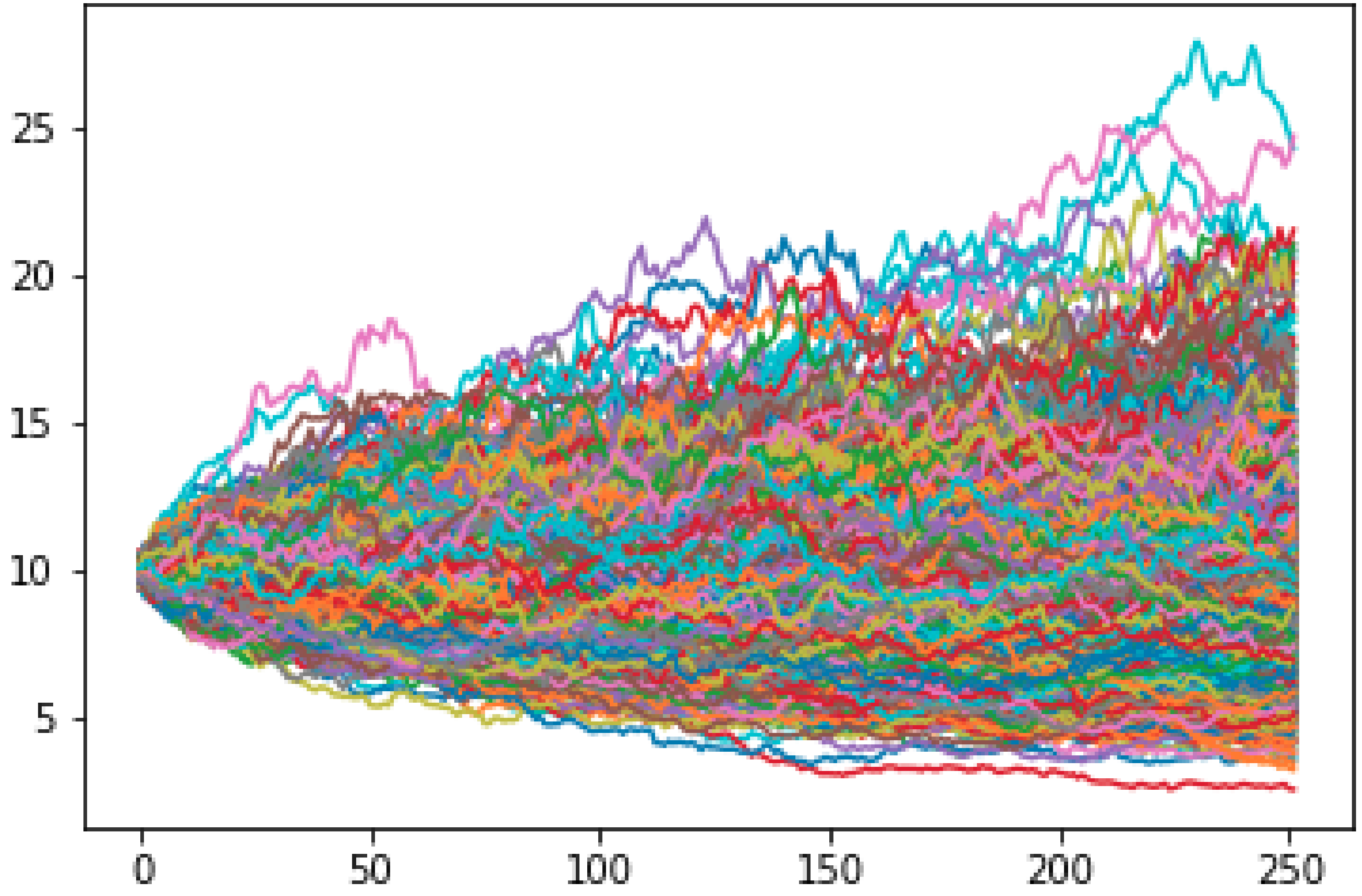
Assuming you have an object `StockReturns` which is a time series of stock returns.

To simulate a random walk:

```
In [1]: mu = np.mean(StockReturns)
In [2]: std = np.std(StockReturns)
In [3]: T = 252
In [4]: S0 = 10
In [5]: rand_rets = np.random.normal(mu,std,T) + 1
In [6]: forecasted_values = S0*(rand_rets.cumprod())
In [7]: forecasted_values
Out [7]: array([ 9.71274884,  9.72536923, 10.03605425 ... ])
```

Monte Carlo Simulations

A series of Monte Carlo simulations of a single asset starting at stock price $10 at T0. Forecasted for 1 year (252 trading days along the x-axis):



Monte Carlo VaR in Python

To calculate the VaR(95) of 100 Monte Carlo simulations:

```
In [1]: mu = 0.0005
In [2]: vol = 0.001
In [3]: T = 252
In [4]: sim_returns = []
In [5]: for i in range(100):
In [6]:     rand_rets = np.random.normal(mu,vol,T)
In [7]:     sim_returns.append(rand_rets)
In [8]: var_95 = np.percentile(sim_returns, 5)
In [9]: var_95
Out [9]: -0.028
```

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Understanding Risk

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Summary

- Moments and Distributions
- Portfolio Composition
- Correlation and Co-Variance
- Markowitz Optimization
- Beta & CAPM
- FAMA French Factor Modeling
- Alpha
- Value at Risk
- Monte Carlo Simulations

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Good luck!