Estimating tail risk

INTRODUCTION TO PORTFOLIO RISK MANAGEMENT IN PYTHON

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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

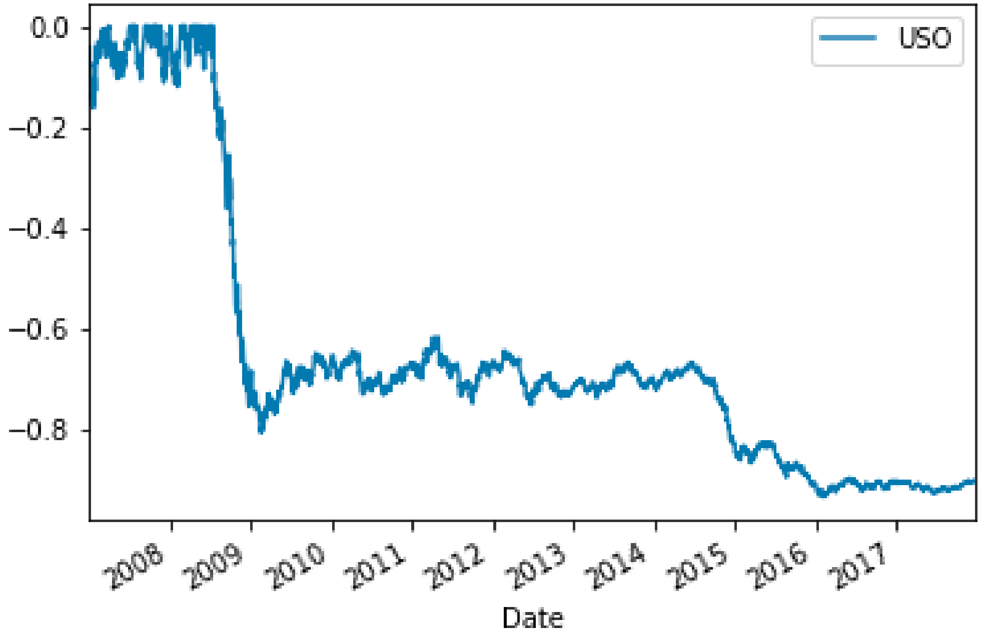
Historical drawdown

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

```
running_max = np.maximum.accumulate(cum_rets)
running_max[running_max < 1] = 1
drawdown = (cum_rets) / running_max - 1
drawdown
```

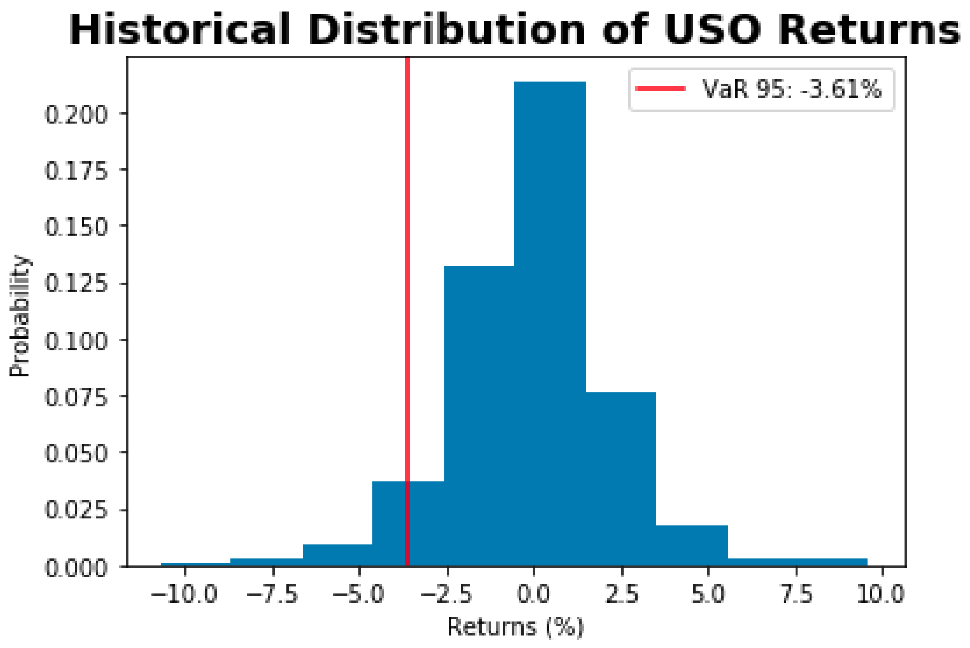
```
Date          Return
2007-01-03    -0.042636
2007-01-04    -0.081589
2007-01-05    -0.073062
```

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

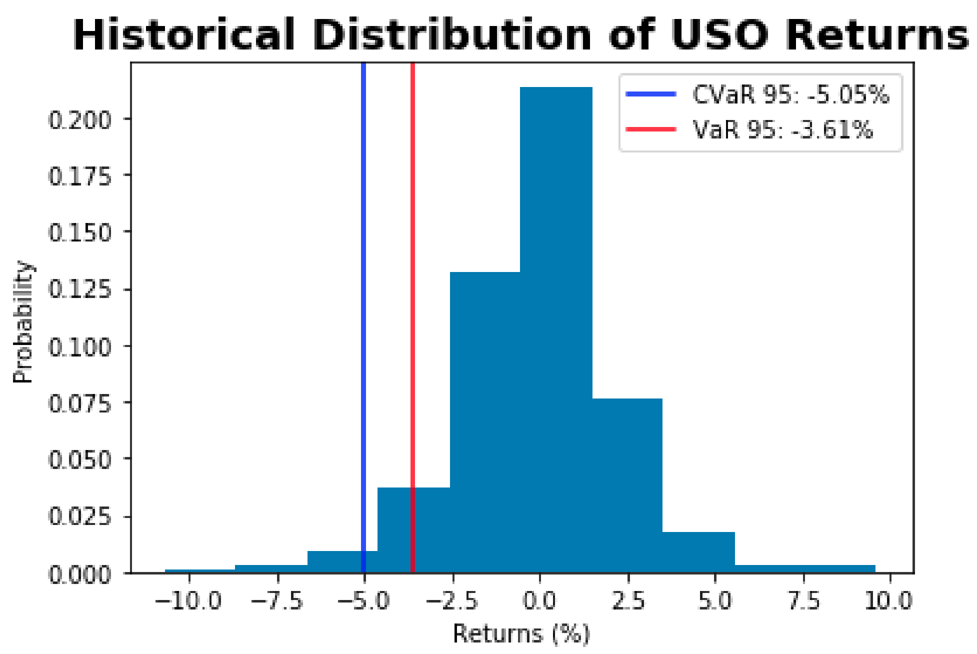
```
var_level = 95
var_95 = np.percentile(StockReturns, 100 - var_level)
var_95
```

```
-0.023
```

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):

```
var_level = 95
var_95 = np.percentile(StockReturns, 100 - var_level)
cvar_95 = StockReturns[StockReturns <= var_95].mean()
cvar_95
```

```
-0.025
```

Let's practice!

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VaR extensions

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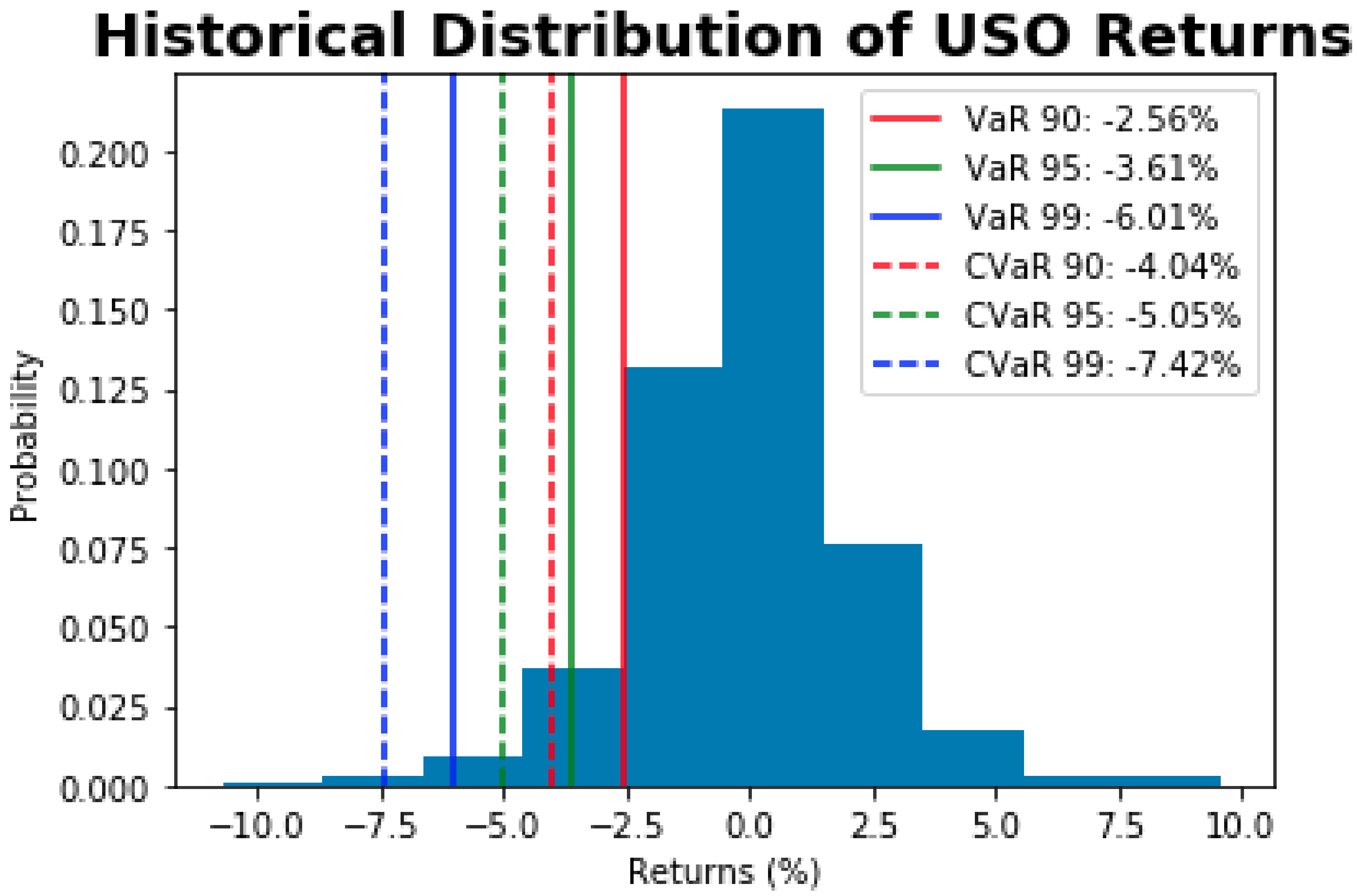
VaR quantiles



Empirical assumptions

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

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

Sample from a probability distribution

Parametric VaR in Python

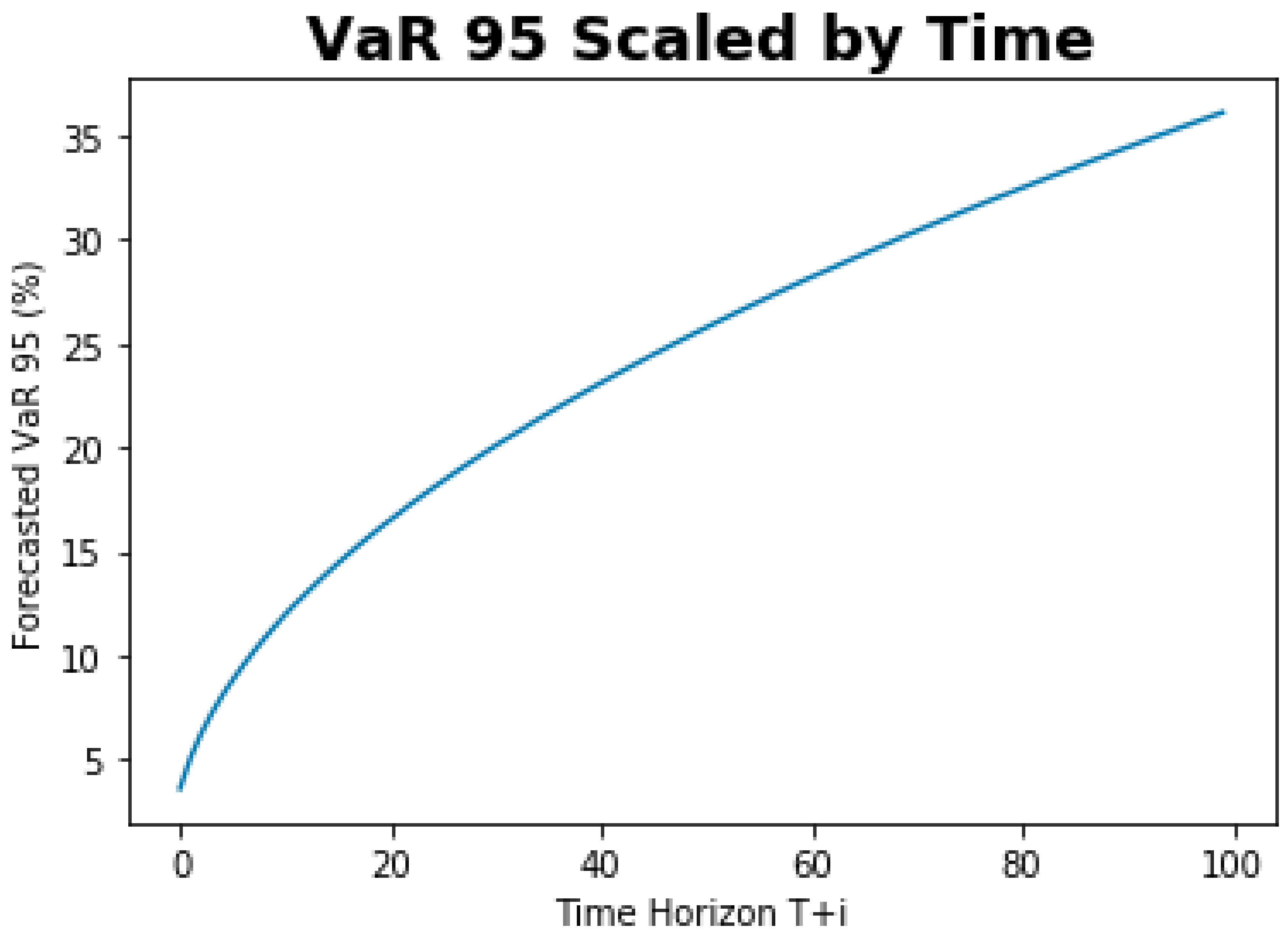
Assuming you have an object `StockReturns` which is a time series of stock returns.

To calculate parametric VaR(95):

```
mu = np.mean(StockReturns)
std = np.std(StockReturns)
confidence_level = 0.05
VaR = norm.ppf(confidence_level, mu, std)
VaR
```

```
-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):

```
forecast_days = 5
forecast_var95_5day = var_95*np.sqrt(forecast_days)
forecast_var95_5day
```

```
-0.0525
```

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Random walks

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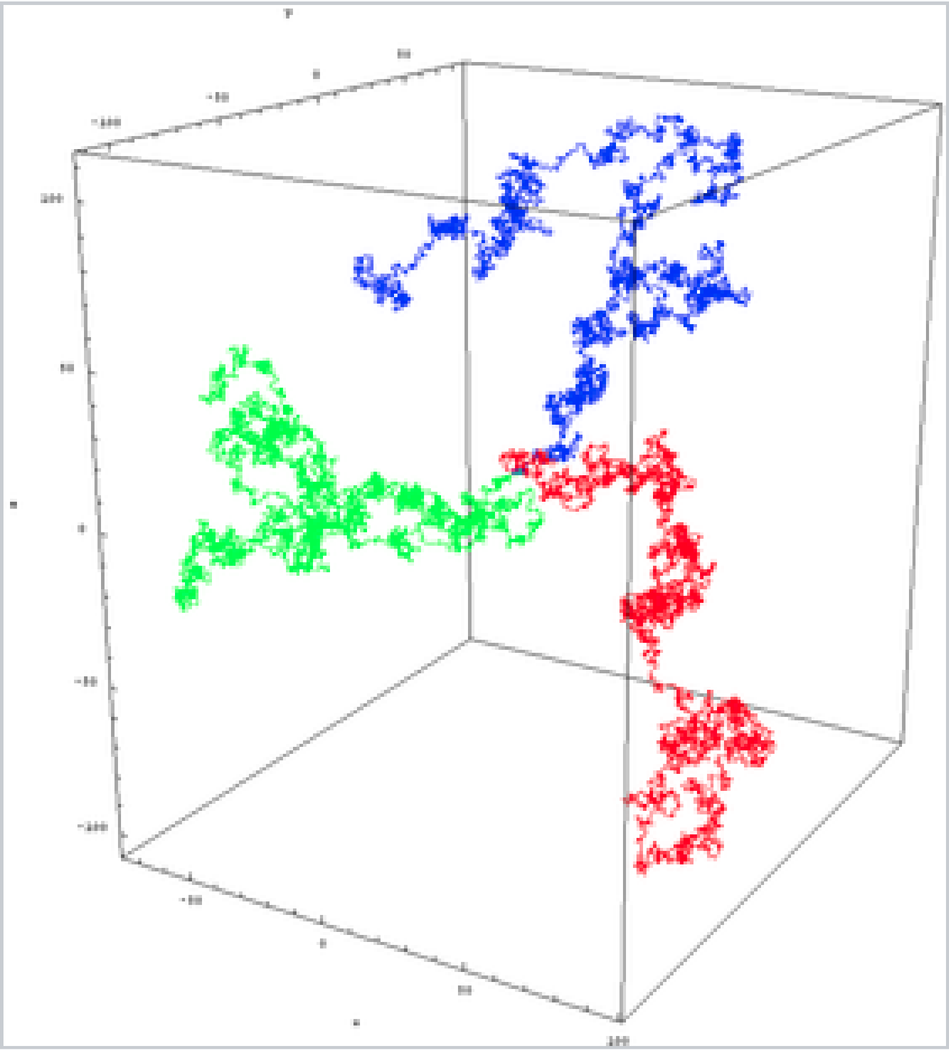
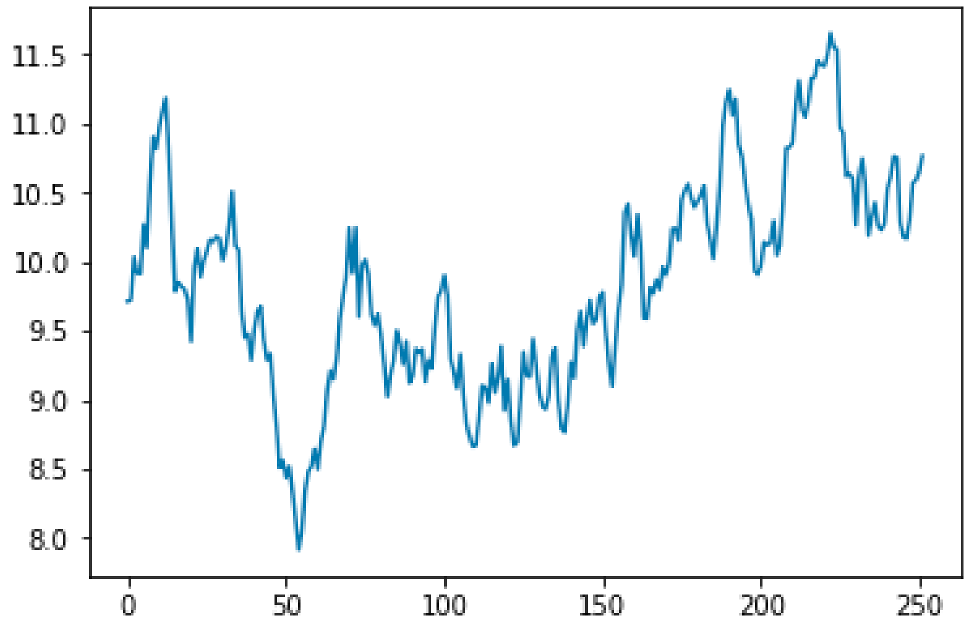
Random walks



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.

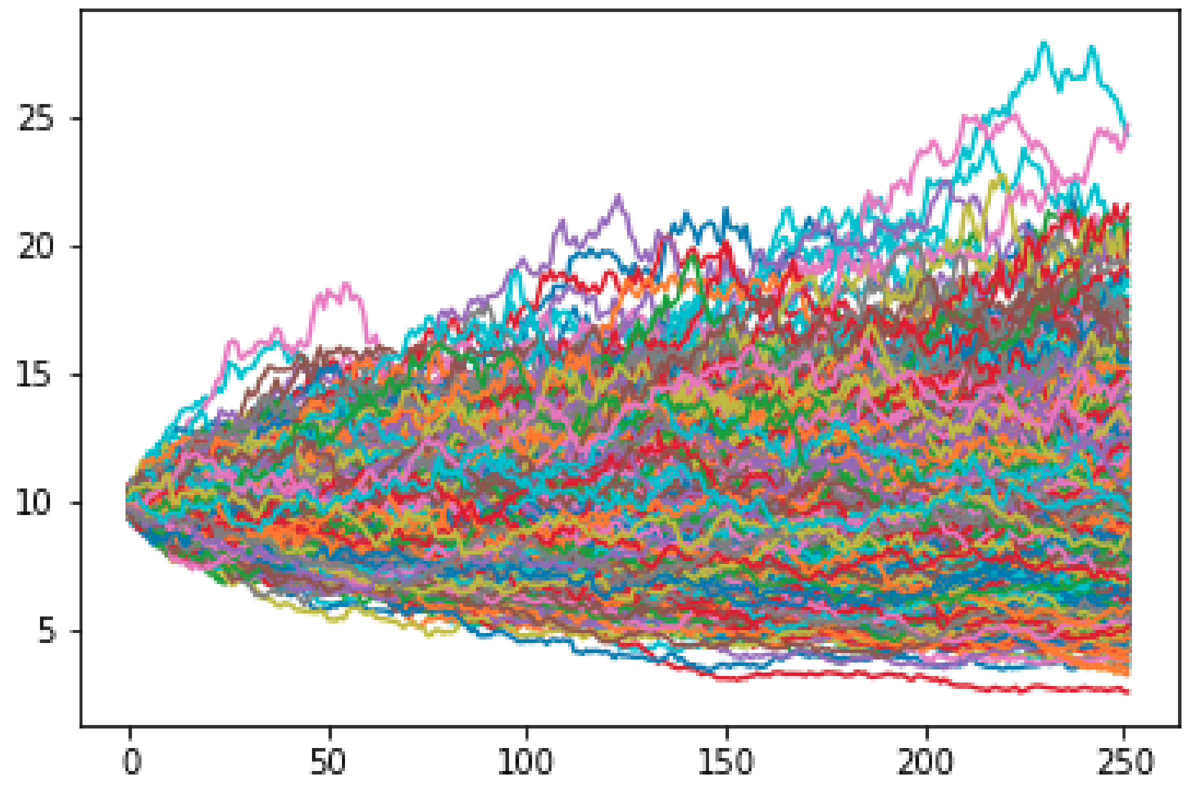
To simulate a random walk:

```
mu = np.mean(StockReturns)
std = np.std(StockReturns)
T = 252
S0 = 10
rand_rets = np.random.normal(mu, std, T) + 1
forecasted_values = S0 * (rand_rets.cumprod())
forecasted_values
```

```
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:

```
mu = 0.0005
vol = 0.001
 T = 252
sim_returns = []
for i in range(100):
    rand_rets = np.random.normal(mu, vol, T)
    sim_returns.append(rand_rets)
var_95 = np.percentile(sim_returns, 5)
var_95
```

```
-0.028
```

Let's practice!

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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

Good luck!

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