Final Report: Knightrade Project

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You could find the project on https://github.com/bagelquant/knightrade.

Project Overview

`Knightrade` is a Python package designed for backtesting. It provides a user-friendly interface for implementing, testing, and optimizing trading strategies. The project emphasizes modularity, scalability, and ease of use, leveraging object-oriented programming (OOP) principles to ensure maintainability and extensibility.

Objectives

1. **Backtesting**: Simulate trading strategies on historical data to evaluate their performance.
2. **Data Handling**: Standardize and preprocess data for trading strategies.
3. **Visualization**: Provide tools for visualizing portfolio performance and strategy results.

Key Modules

1. Data Module

The data module is responsible for handling raw data, transforming it into a standardized format, and preprocessing it for trading strategies.

- **Standard Data**: Provides a consistent data structure (`TimeSeries` and `CrossSection`) for type hinting and manipulation.
- **Data Handler**: Loads data from various sources and converts it into the standard format.
- **Data Preprocessor**: Cleans, normalizes, and transforms data for strategy use.

2. Strategy Module

The strategy module defines trading strategies that generate buy/sell signals based on market conditions. It includes:

- Abstract base class `Strategy` for defining the interface.
- Concrete implementations like `SimpleMovingAverageStrategy`, `MomentumStrategy`, and `RSI_Strategy`.

3. Backtest Module

The backtest module simulates the execution of trading strategies on historical data. It calculates portfolio performance, including cash, positions, and total portfolio value over time.

4. Visualization Module

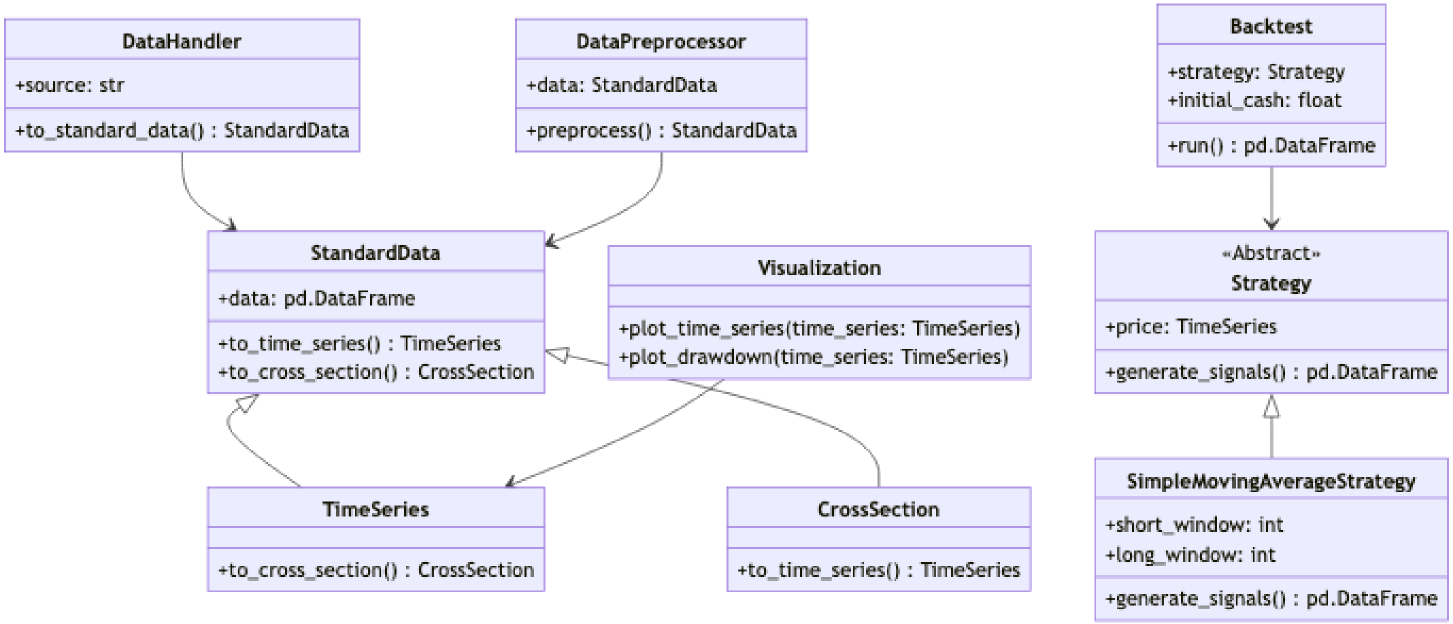
The visualization module provides tools for plotting time series data and portfolio performance metrics, such as drawdowns.

File Structure

```
.
|-- src/
|   |-- knightrade/
|   |   |-- __init__.py
|   |   |-- data_module/
|   |   |   |-- __init__.py
|   |   |   |-- data_handler.py
|   |   |   |-- data_preprocessor.py
|   |   |   |-- standard_data.py
|   |   |-- strategy.py
|   |   |-- backtest.py
|   |   |-- visualization.py
|-- docs/
|   |-- attachments/
|   |-- final_report.md
|   |-- strategy.md
|   |-- visualization.md
|   |-- data_module.md
|-- tests/
|-- README.md
|-- pyproject.toml
|-- main.py
|-- LICENSE
```

Object-Oriented Design

The project follows an OOP approach, with clear abstractions and relationships between classes. Below is a mermaid diagram illustrating the design:


DataHandler
+source: str
+to_standard_data() : StandardData
DataPreprocessor
+data: StandardData
+preprocess() : StandardData
Backtest
+strategy: Strategy
+initial_cash: float
+run() : pd.DataFrame
StandardData
+data: pd.DataFrame
+to_time_series() : TimeSeries
+to_cross_section() : CrossSection
Visualization
+plot_time_series(time_series: TimeSeries)
+plot_drawdown(time_series: TimeSeries)
«Abstract»
Strategy
+price: TimeSeries
+generate_signals() : pd.DataFrame
TimeSeries
+to_cross_section() : CrossSection
CrossSection
+to_time_series() : TimeSeries
SimpleMovingAverageStrategy
+short_window: int
+long_window: int
+generate_signals() : pd.DataFrame

Example Workflow

1. **Data Handling**:
    - Load raw data using `DataHandler`.
    - Convert it to a `TimeSeries` object.
2. **Strategy Definition**:
    - Define a trading strategy, e.g., `SimpleMovingAverageStrategy`.
3. **Backtesting**:
    - Use the `Backtest` class to simulate the strategy on historical data.
4. **Visualization**:

- Plot portfolio performance and drawdowns using the `Visualization` module.

Example Code

The following example demonstrates how to use the `Knightrade` package, it will output two figures:

- a portfolio value figure
- a drawdown figure

You could find the figures at the end of this report.

```
import matplotlib.pyplot as plt
import pandas as pd
from time import perf_counter
from src.knightrade import read_yfinance, TimeSeries
from src.knightrade import SimpleMovingAverageStrategy, MeanReversionStrategy, Strategy
from src.knightrade import Backtest, plot_time_series, plot_drawdown
from dataclasses import dataclass



def main() -> None:
    """
    Main function to demonstrate the usage of the trading strategies.
    """

    # 1. Read data from Yahoo Finance using DataHandler module
    data_time_series = read_yfinance(tickers=["AAPL", "NVDA"], start="2020-01-01", end="2023-01-01", column="Close")

    # 2. Initialize the strategies
    sma = SimpleMovingAverageStrategy(_price=data_time_series,
                                      short_window=10,
                                      long_window=10,
                                      amount=100)
    mean_reversion = MeanReversionStrategy(_price=data_time_series,
                                           window=10,
                                           amount=100)
```

```python
# 2.1 Customize a strategy
@dataclass(slots=True)
class CustomStrategy(Strategy):
    """
    A simple custom strategy that inherits from Strategy.

    Long only when the price is above the moving average.
    """
    long_window: int        # Moving average window
    amount: float = 100.0   # Amount to buy

    def generate_signals(self) -> TimeSeries:
        """
        Generate buy/sell signals based on the moving average.

        ** This function is required to be implemented in the derived class. **
        ** abstractmethod. **
        """
        price = self._price.data.copy()
        signals = pd.DataFrame(index=price.index, columns=price.columns)
        # set signals type to float
        signals = signals.astype(float)

        # Calculate moving average
        mavg = price.rolling(window=self.long_window, min_periods=self.long_window).mean().shift(1)

        # Generate signals
        signals[price > mavg] = self.amount

        # set signals type to float
        signals = signals.astype(float)
        signals = signals.ffill().fillna(0)
        signals = TimeSeries(signals)
        return signals
    # 2.2 Initialize the custom strategy
    custom_strategy = CustomStrategy(_price=data_time_series,
                                      long_window=10,
                                      amount=100)

    # 3. Run the backtest

    sma_bt = Backtest(strategy=sma, price=data_time_series)
    mean_reversion_bt = Backtest(strategy=mean_reversion, price=data_time_series)
    custom_strategy_bt = Backtest(strategy=custom_strategy, price=data_time_series)

    # 4. Run the backtest
    sma_bt.run()
    mean_reversion_bt.run()
    custom_strategy_bt.run()

    # 4.1 Obtain the portfolio value
    portfolio_value_sma = sma_bt.portfolio.data
    portfolio_value_mean_reversion = mean_reversion_bt.portfolio.data
    portfolio_value_custom_strategy = custom_strategy_bt.portfolio.data
    result = TimeSeries(pd.concat([portfolio_value_sma,
                                   portfolio_value_mean_reversion,
                                   portfolio_value_custom_strategy], axis=1).sort_index())
    result.data.columns = ["SMA", "Mean Reversion", "Custom Strategy"]

    # 5. visualize the results
    fig_portfolio = plot_time_series(result, title="Different Strategies Backtest")
    fig_drawdown = plot_drawdown(result, title="Drawdown Backtest")
    fig_portfolio.show()
    fig_drawdown.show()
    plt.show()


if __name__ == "__main__":
    start_time = perf_counter()
    main()

    end_time = perf_counter()
    print(f"Execution time: {end_time - start_time:.2f} seconds \n or {end_time - start_time:.2f} minutes")
```

Achievements

- Implemented core modules for data handling, strategy definition, backtesting, and visualization.
- Designed a modular and extensible architecture using OOP principles.
- Established a foundation for future work on optimization.

Modules Docs

Data Module

Handles raw data preprocessing and transformation into a standardized format. Includes:

- **Standard Data**: Defines a consistent data structure for type hinting and manipulation.
- **Data Handler**: Converts data from various sources (e.g., local files, Yahoo Finance) into the standard format.

Standard Data Object Standard Data Object is a class that provides a standard data structure for the project. It is a simple wrapper around `pandas.DataFrame` with some additional methods. It is used to ensure the data is in a consistent format. Especially for type hinting and data manipulation.

There are two types of data objects in the project:

- class `CrossSection`
- class `TimeSeries`

Both class have similar structure, the main difference is the data structure. The `CrossSection.data` is a `DataFrame` with `TimeStamp` as columns, while the `TimeSeries.data` is a `DataFrame` with `TimeStamp` as index.

In short, you could easily convert one to another by transposing the `DataFrame`.

These standard data objects are used in the project to ensure the data is in a consistent format. Especially for **type hinting** and data manipulation.

Data Handler Provide an easy interface to convert data from different sources to a standard data object

Data source: - local file - `pandas.DataFrame` - `.csv` file - `.json` file - `.xlsx` file - remote file - `yahoo finance`

This module is a function-based module, all functions are stateless and could be used independently.

Strategy Module

Defines trading strategies that generate buy/sell signals based on market conditions. Includes:

- Abstract base class `Strategy` for defining the interface.
- Implementations like `SimpleMovingAverageStrategy`, `MomentumStrategy`, `MeanReversionStrategy`, and others.

This module allows users to create custom strategies by inheriting from the `Strategy` class and implementing the `generate_signals` method.

sample custom strategy:

```python
import pandas as pd
from dataclasses import dataclass
from src.knightrade import Strategy, TimeSeries


@dataclass(slots=True)
class CustomStrategy(Strategy):
    """
    A simple custom strategy that inherits from Strategy.

    Long only when the price is above the moving average.
    """
    # add users custom parameters here
    long_window: int  # Moving average window
    amount: float = 100.0  # Amount to buy

    def generate_signals(self) -> TimeSeries:
        """
        Generate buy/sell signals based on the moving average.

        ** This function is required to be implemented in the derived class. **
        ** abstractmethod. **
        """

        # Add user custom logic here, signals is a TimeSeries object

        # set signals type to float
        signals = pd.DataFrame()
        signals = TimeSeries(signals)
        return signals
```

Abstract Base Class: `Strategy` The `Strategy` class is an abstract base class that defines the interface for all trading strategies. It includes the following attributes and methods:

- **Attributes**:
  - `price`: A `TimeSeries` object representing the price data.
- **Methods**:
  - `generate_signals()`: An abstract method that must be implemented by all subclasses to generate buy/sell signals.

Simple Moving Average Strategy: `SimpleMovingAverageStrategy` This strategy generates buy/sell signals based on the crossing of two moving averages.

- **Attributes**:
  - `short_window`: The window size for the short moving average.
  - `long_window`: The window size for the long moving average.
  - `amount`: The amount to buy/sell (default is 1.0).
- **Logic**:
  - Buy signals are generated when the price is above the short moving average.
  - Sell signals are generated when the price is below the long moving average.

Momentum Strategy: `MomentumStrategy` This strategy generates buy/sell signals based on the momentum of the price.

- **Attributes**:
  - `window`: The window size for calculating momentum.
  - `amount`: The amount to buy/sell (default is 1.0).
- **Logic**:
  - Buy signals are generated when momentum is positive.

  - Sell signals are generated when momentum is negative.

Mean Reversion Strategy: `MeanReversionStrategy` This strategy generates buy/sell signals based on the mean reversion of the price.

- **Attributes**:
  - `window`: The window size for calculating the rolling mean and standard deviation.
  - `amount`: The amount to buy/sell (default is 1.0).
- **Logic**:
  - Buy signals are generated when the price is below the rolling mean minus one standard deviation.
  - Sell signals are generated when the price is above the rolling mean plus one standard deviation.

Bollinger Bands Strategy: `BollingerBandsStrategy` This strategy generates buy/sell signals based on the Bollinger Bands.

- **Attributes**:
  - `window`: The window size for calculating the rolling mean and standard deviation.
  - `num_std_dev`: The number of standard deviations for the bands.
  - `amount`: The amount to buy/sell (default is 1.0).
- **Logic**:
  - Buy signals are generated when the price is below the lower Bollinger Band.
  - Sell signals are generated when the price is above the upper Bollinger Band.

Relative Strength Index (RSI) Strategy: `RSI_Strategy` This strategy generates buy/sell signals based on the Relative Strength Index (RSI).

- **Attributes**:
  - `window`: The window size for calculating RSI.
  - `overbought`: The RSI threshold for overbought conditions (default is 70.0).
  - `oversold`: The RSI threshold for oversold conditions (default is 30.0).
  - `amount`: The amount to buy/sell (default is 1.0).
- **Logic**:
  - Buy signals are generated when the RSI is below the oversold threshold.
  - Sell signals are generated when the RSI is above the overbought threshold.

Backtest Module

The `Backtest` class is the core of this module. It simulates the execution of a trading strategy and tracks portfolio performance.

Attributes

- **strategy** (`Strategy`): The trading strategy to be backtested. It generates buy/sell signals.
- **price** (`TimeSeries`): Historical price data for the assets being traded.
- **initial_cash** (`float`): The starting cash balance for the backtest. Default is 1,000,000.
- **portfolio** (`TimeSeries`): The total portfolio value (cash + positions) over time.
- **position** (`TimeSeries`): The position sizes for each asset over time.
- **cash** (`TimeSeries`): The cash balance over time.

Methods

- **`__post_init__()`**: Initializes the position attribute by generating signals from the strategy.
- **`run()`**: Executes the backtest by calculating portfolio value and cash balance over time.

Visualization Module

Provides tools for visualizing time series data and portfolio performance metrics, such as drawdowns.

Future Work

1. **Transaction Costs**: Incorporate transaction costs and slippage into the backtest module.
2. **Performance Metrics**: Add metrics like Sharpe ratio, maximum drawdown, and alpha.
3. **Optimization**: Implement parameter optimization for strategies.
4. **Live Trading**: Extend the package for live trading integration with brokers.

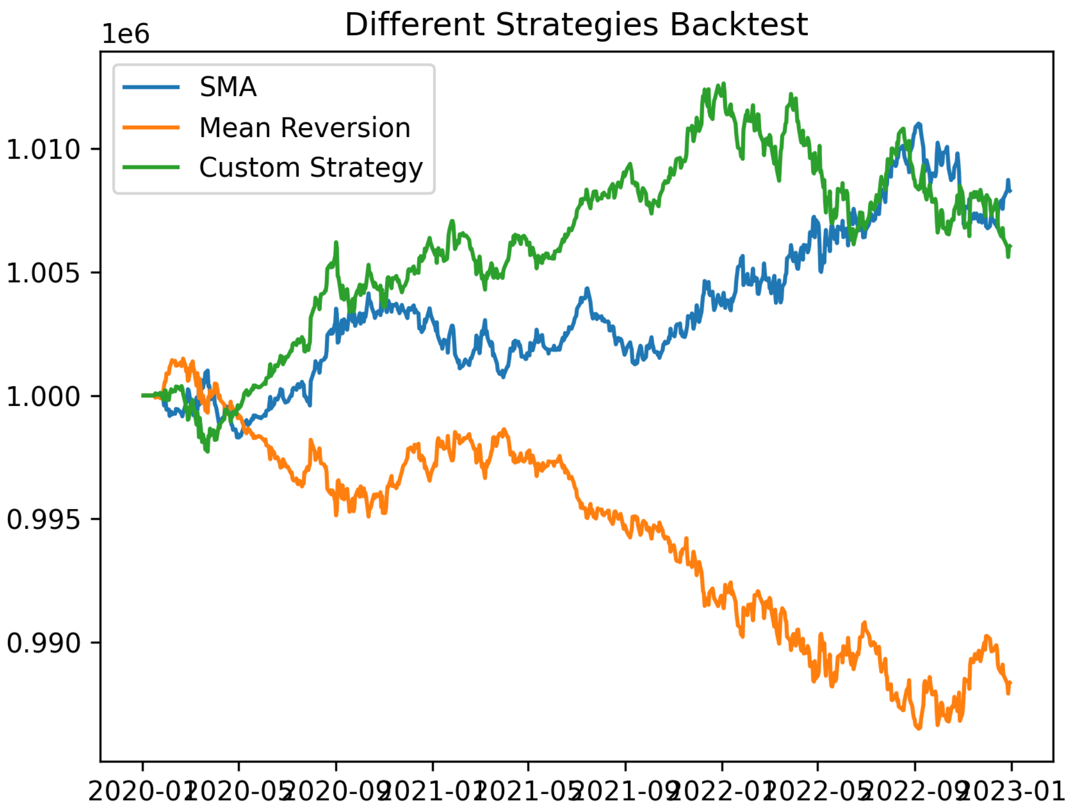


Figure 1: Portfolio Value Figure

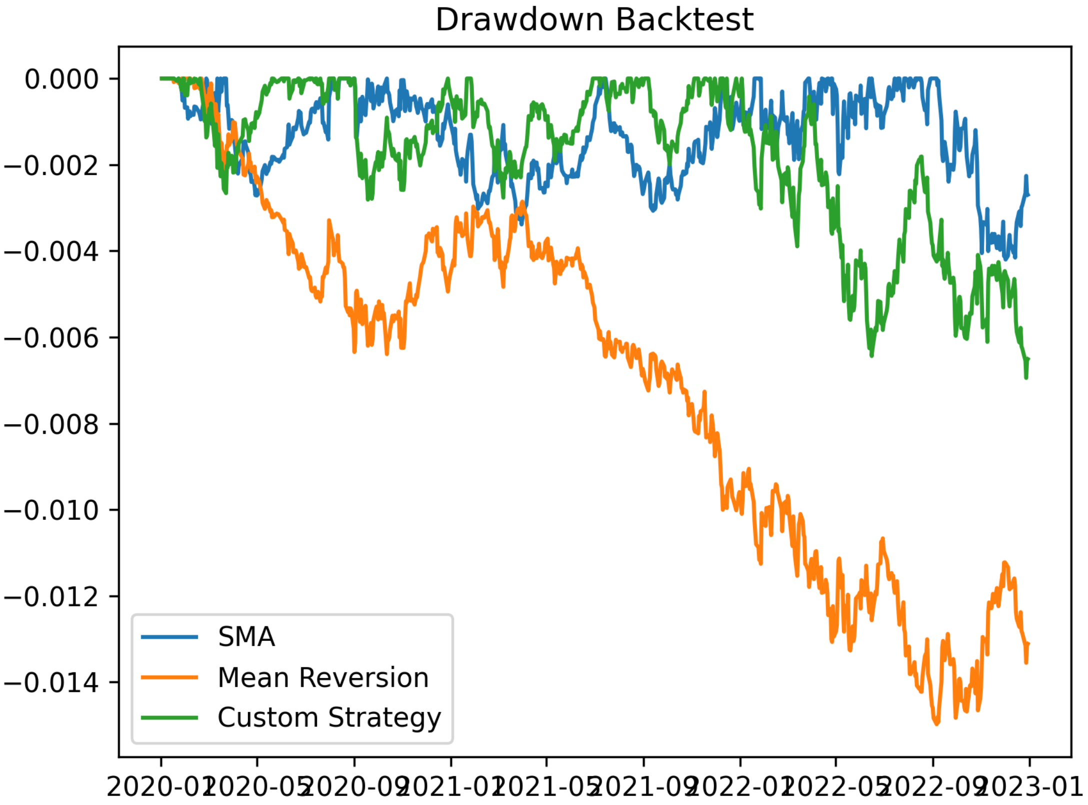


Figure 2: Drawdown Figure