Multi-Layer Perceptron for Optimal Equity Derivative Hedging

Team 10: Bay Area Data Science Summit 2025

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Problem Restatement

(Known factors)

Focus:

1. Minimize costs while exceeding daily exposure.

Factors:

1. Unaware of future data when making decisions
2. Premium is our cost
3. Options shifts based on strike and expiration date.

Assumptions:

1. For each individual day, suppose a scenario for spot move given below:

	Beta	%move
SPY	1	3.0%
IWM	1.21	3.6%
QQQ	1.36	4.1%

2. Market closed on weekends, do no consider weekend data.

Two Main Goals

Daily Exposure ≥ $10,000,000

$$k = \textbf{strike};\ \ S_{\textbf{day}}(t) = \textbf{Undl Price};\ \ S_{\textbf{day}}(t+1) = \textbf{Undl Price} \times \left(1 + \%\textbf{move}\right)$$

Call Option

$$\textbf{Exposure}_{\textbf{day}}(t) = \max\left(S_{\textbf{day}}(t) - k, 0\right) - \max\left(S_{\textbf{day}}(t-1) - k, 0\right)$$

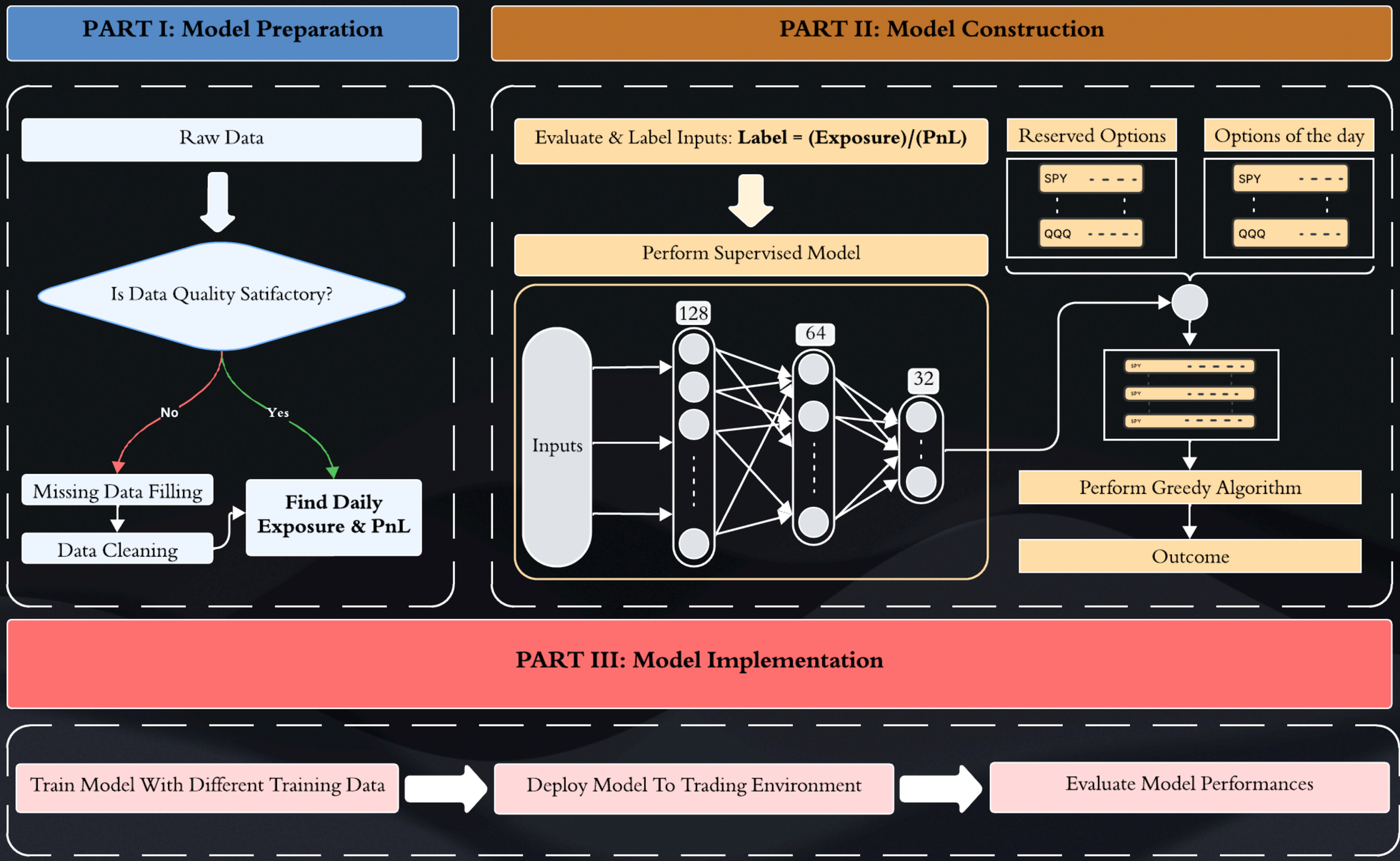
Put Option

$$\textbf{Exposure}_{\textbf{day}}(t) = \max\left(k - S_{\textbf{day}}(t), 0\right) - \max\left(k - S_{\textbf{day}}(t-1), 0\right)$$

Minimizing Cost

$$\textbf{Premium Paid} = \textbf{(Ask price at Day(0))} \times (\#\ \textbf{of options})$$

Model Diagram



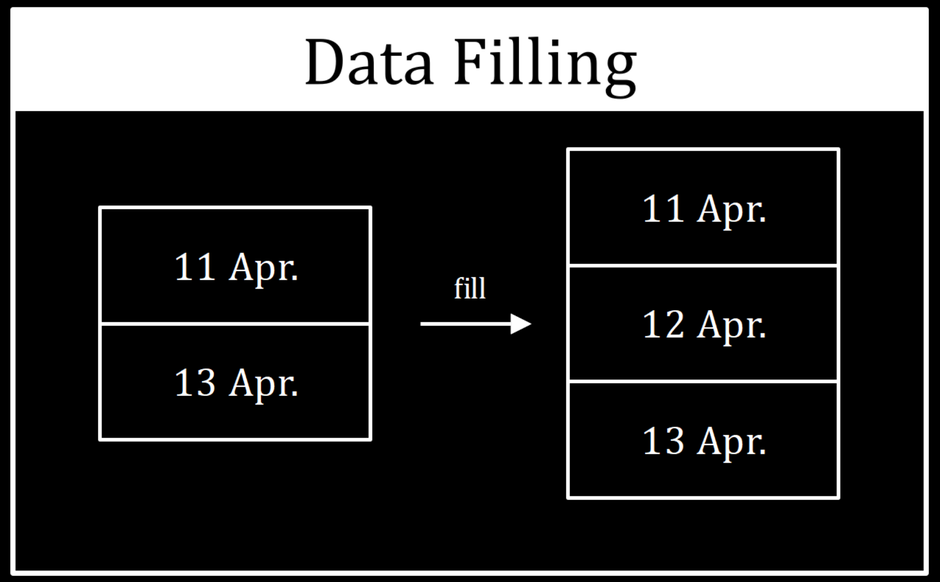
Data Preprocessing

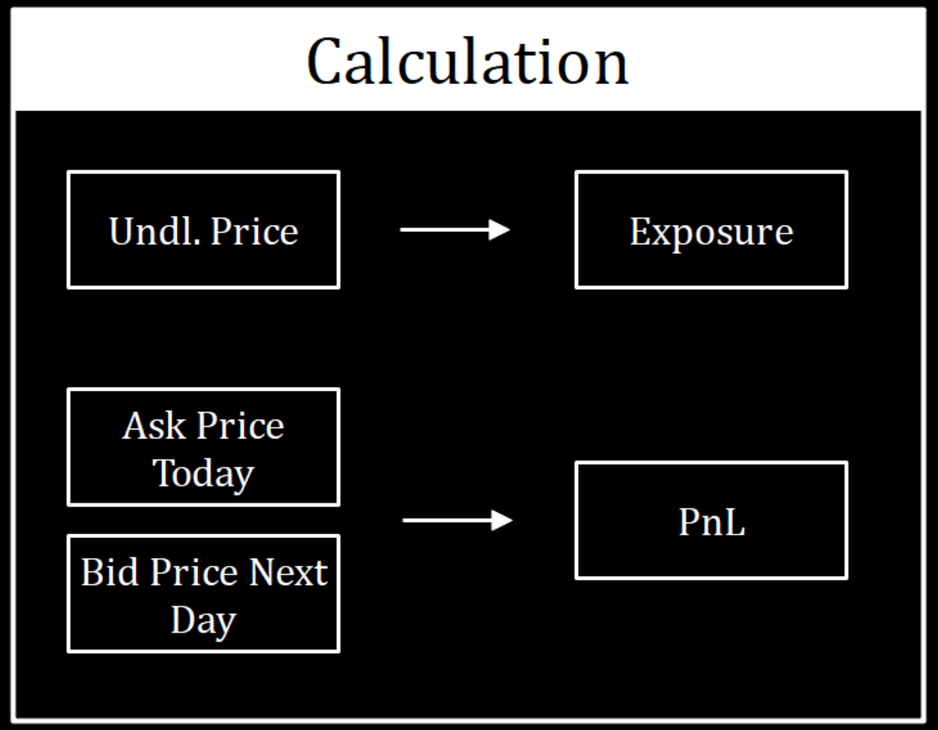
Data Filling:

- **Intentionally skip weekends**
- **Make sure each identical options have a row each day before expiring**

Calculation:

- **PnL and exposure each day**





Labeling

Greedy:

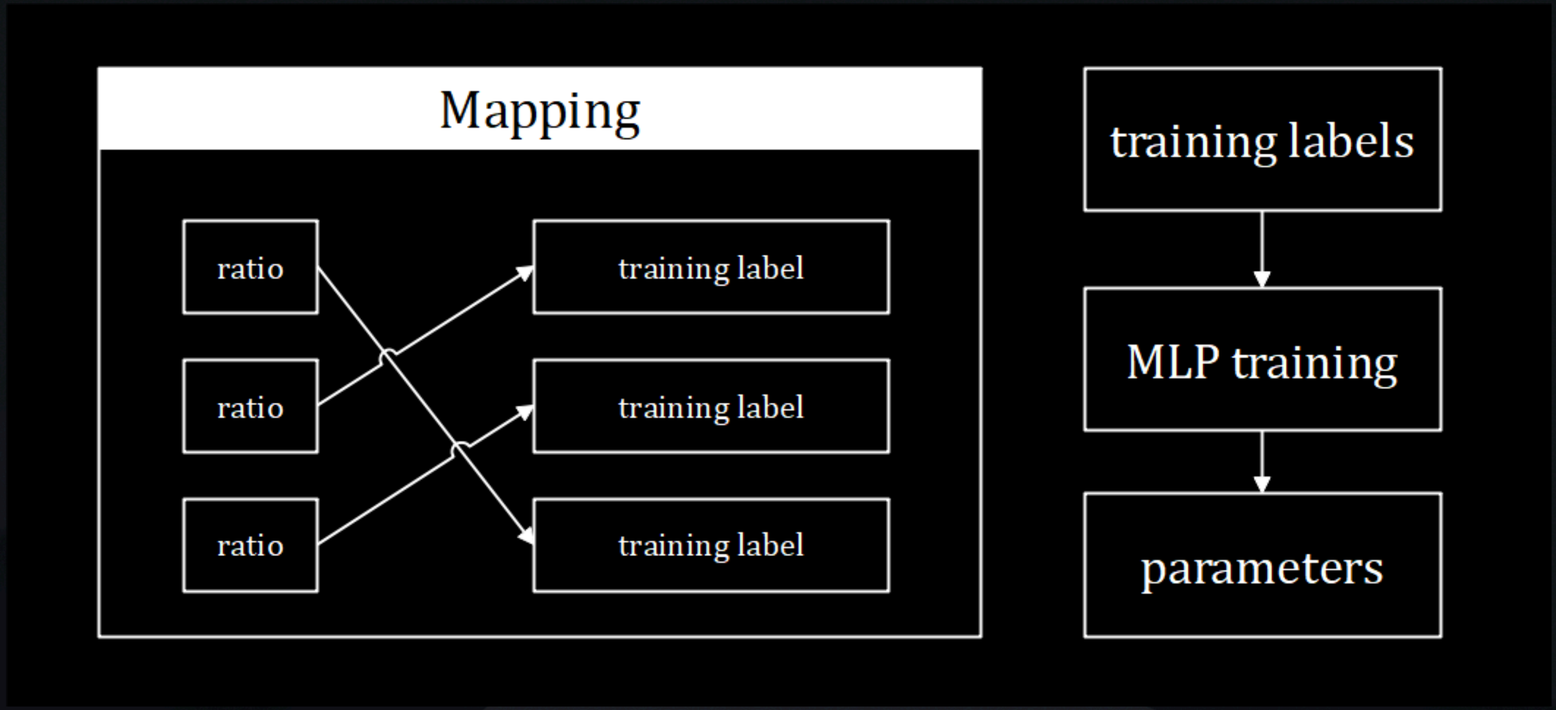
Assume you can sell all you buy the next day

Standard:

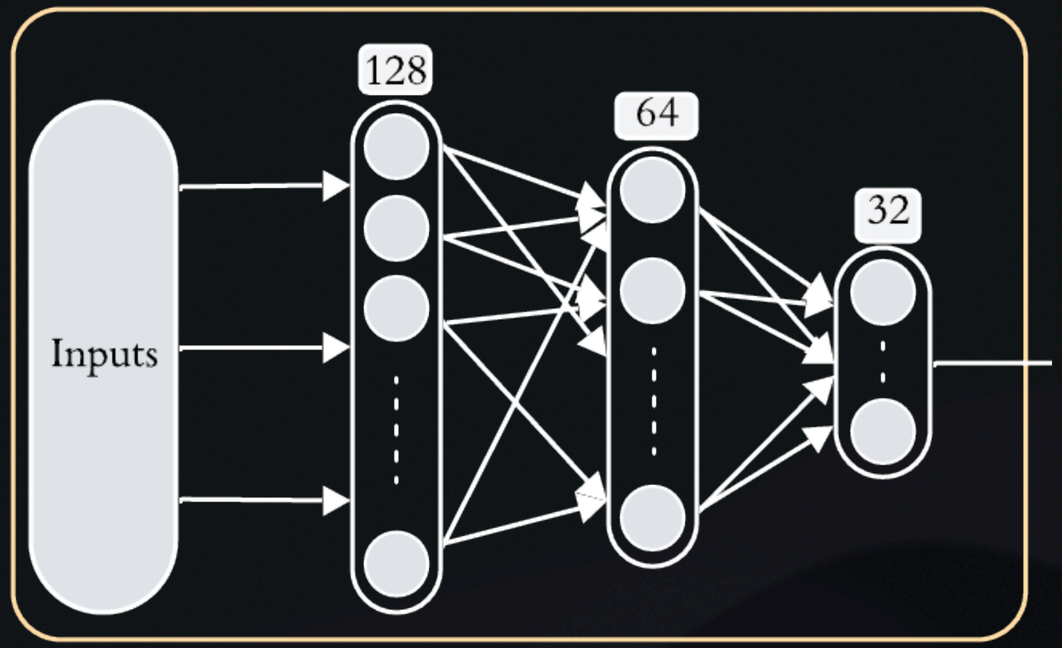
$$ratio = \frac{exposure}{PnL}$$

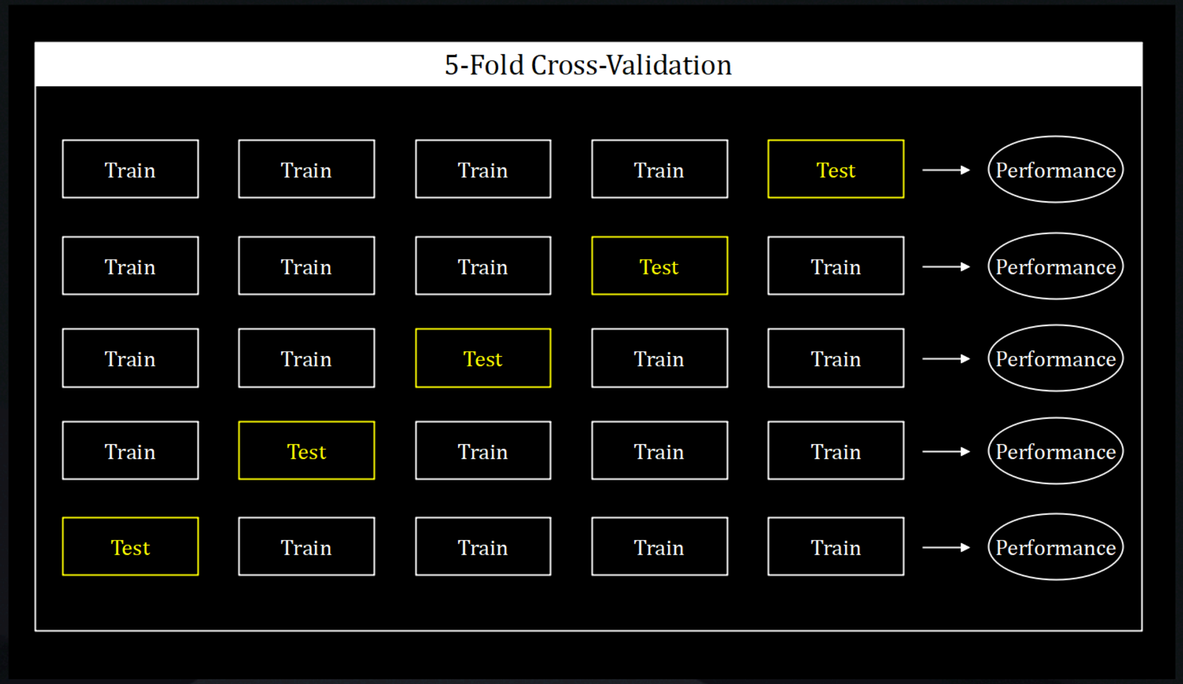
Priority: Positive > Negative > 0

Labeling: Map to one value



Network Training





Multi-Layer Perceptron(MLP)

Layer Size:

128>64>32>1

Avoid Overfitting:

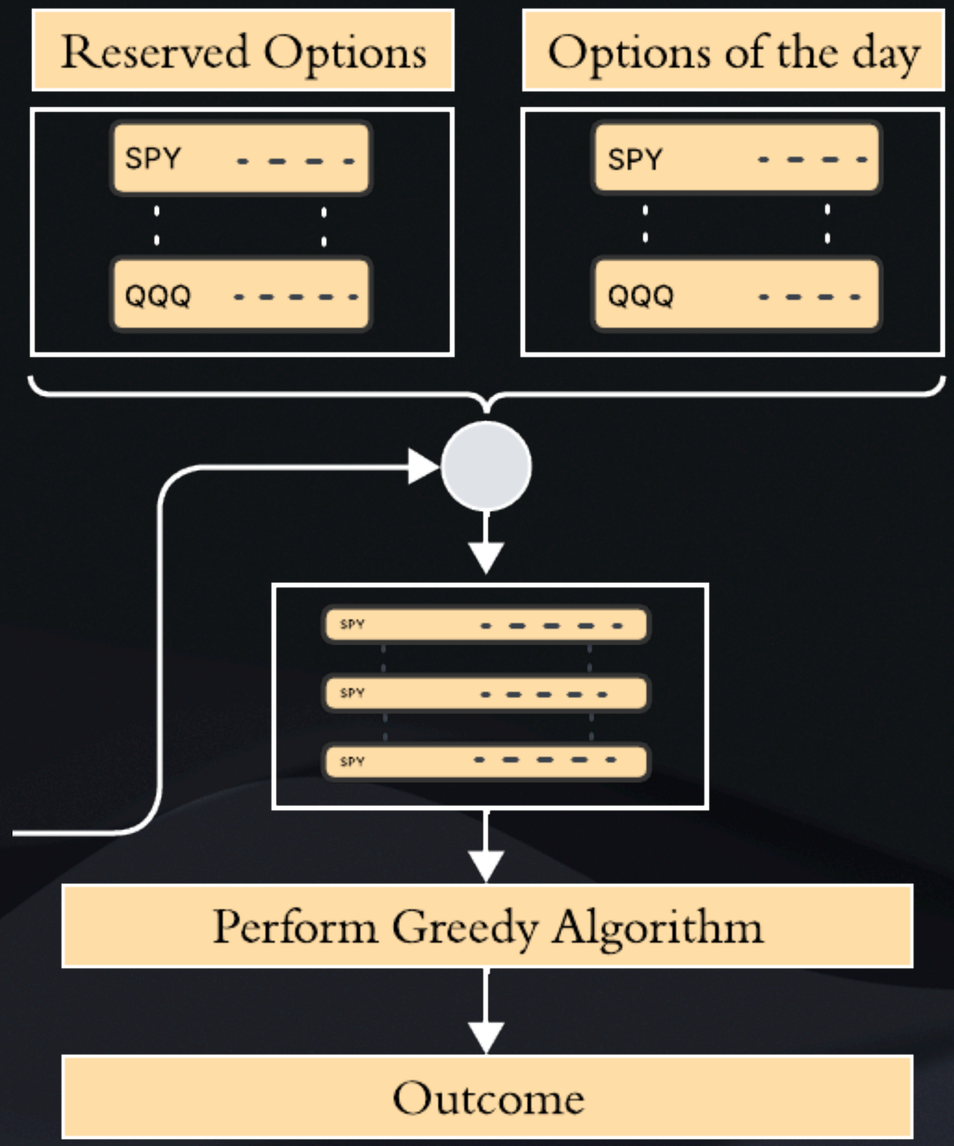
Based on training data without overfitting too much

Cross-Validation:

Use the method of 5-fold cross-validation

Decision Logic

1. Put all you can sell into a dictionary/list
2. Check whether the rest reaches the target
3. If so, skip. Else operate according to priority
4. For each option:
    1) Reduce selling dictionary/list
    2) Increase purchase amount
    3) Once reaching target, skip



Model Performance Metrics

	Random Sorting (Baseline)	Known label (Ideal Situation)	Our Model (Trained result)
Training Set	Cost $11,097,348	Profit $5,552,290	Profit $2,779,349
Testing Set	Cost $11,299,563	Profit $22,560,857	Cost $4,008,825

```
                holdings = new_holdings.copy()
                total_PnL += PnL

            mean_PnL += total_PnL

    mean_PnL /= 25
    print("The mean total PnL of baseline is:",mean_PnL *100)
```

✓ 42.6s

```
The mean total PnL of baseline is: -11299563.119999997
```

```
        for key, qty in holdings.items():
            maturity_id, strike, symbol = key
            next_key = (maturity_id, strike, symbol)
            if maturity_id > iterdate + 1:
                new_holdings[next_key] = qty
        holdings = new_holdings.copy()

        total_PnL += PnL

    print("The total PnL is:",total_PnL *100)
```

✓ 2.7s

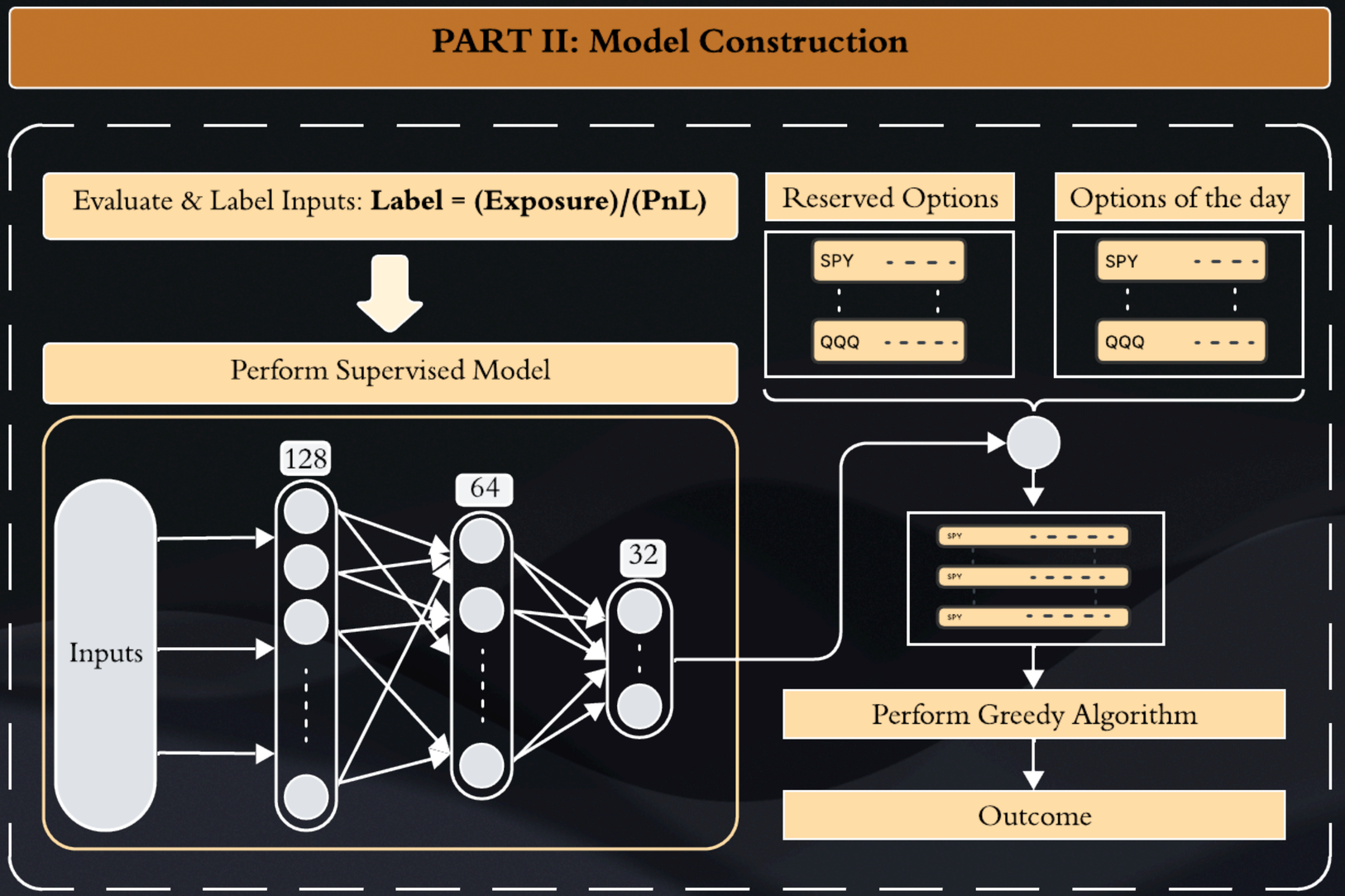
```
The total PnL is: 22560856.999999993
```

```
 === Date 22 ===
Starting new day, current holdings:
{(26, 565.0, 'SPY'): 1268, (28, 224.0, 'IWM'): 511, (27, 224.0, 'IWM'): 546, (28, 2
29/29 [==============================] - 0s 464us/step
Date: 22
Buy orders: {(30, 574.0, 'SPY'): 1249, (31, 224.0, 'IWM'): 266, (31, 222.0, 'IWM'):
Sell orders: {(26, 565.0, 'SPY'): 1268, (28, 224.0, 'IWM'): 511, (27, 224.0, 'IWM')
Exposure: 10000172.846000025
PnL: -291910.99999999994

Total PnL: -4008825.0

Daily trade report exported to 'daily_trade_report.txt'
```

Final Design - Why it is suitable for this problem



1.Exposure & PnL with a mapping function

2.Automatically generate sortable labels

3.Smart buy-sell greedy strategy adjustments

4.MLP captures non-linear market features

5.Independent components, easy upgrades

6.Ready for advanced deep learning module

Insights and Ideas

How to evaluate and optimize feature importance?

How to dynamically adjust Exposure to market conditions?

How to make the model more adaptable to evolving markets?

Thank You!