# COP4533 – Final Project

## Group Members

- Miciel Kirsten Palanca
- Khai Dao

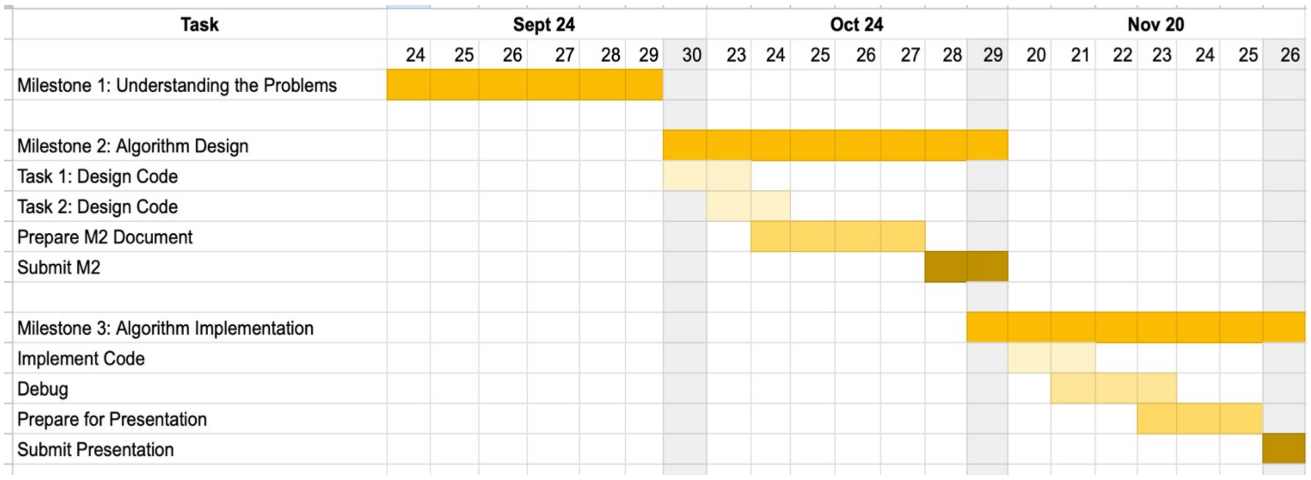
## Member Roles

Miciel Kirsten Palanca – Lead, Developer

## Communication Methods

Further discussion of communication methods is unnecessary, as I am solely responsible for leading and executing the project.

## Gantt Chart for the Project



| Task | Sept 24 | | | | | | | Oct 24 | | | | | | | Nov 20 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| Milestone 1: Understanding the Problems | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| Milestone 2: Algorithm Design | | | | | | | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | | | | | | | |
| Task 1: Design Code | | | | | | | 🟨 | 🟨 | | | | | | | | | | | | | |
| Task 2: Design Code | | | | | | | | 🟨 | 🟨 | | | | | | | | | | | | |
| Prepare M2 Document | | | | | | | | | 🟨 | 🟨 | 🟨 | 🟨 | | | | | | | | | |
| Submit M2 | | | | | | | | | | | | | 🟫 | 🟫 | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| Milestone 3: Algorithm Implementation | | | | | | | | | | | | | | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 | 🟨 |
| Implement Code | | | | | | | | | | | | | | | 🟨 | 🟨 | | | | | |
| Debug | | | | | | | | | | | | | | | | 🟨 | 🟨 | 🟨 | | | |
| Prepare for Presentation | | | | | | | | | | | | | | | | | | 🟨 | 🟨 | 🟨 | |
| Submit Presentation | | | | | | | | | | | | | | | | | | | | | 🟫 |

## Git Repository Link:

https://github.com/micielkirsten/COP4533-Final-Project

**Problem 1 Solution:**

**Input Matrix A:**

$$A = \begin{pmatrix} 12 & 1 & 5 & 3 & 16 \\ 4 & 4 & 13 & 4 & 9 \\ 6 & 8 & 6 & 1 & 2 \\ 14 & 3 & 4 & 8 & 10 \end{pmatrix}$$

**Step 1:** Begin with the input matrix A as provided.

**Step 2:** For each stock, calculate the potential profit that could be obtained by selling the stock on each day after buying it. To do this, subtract the buying price (the price on the day you buy) from the selling price (the price on each subsequent day). Keep track of these potential profits for each stock.

Calculate the potential profits for each stock:

1. Stock 1 (12):

   Buying on Day 1 and selling on Day 2: 1 - 12 = -11

   Buying on Day 1 and selling on Day 3: 5 - 12 = -7

   Buying on Day 1 and selling on Day 4: 3 - 12 = -9

2. Stock 2 (1):

   Buying on Day 1 and selling on Day 2: 4 - 1 = 3

   Buying on Day 1 and selling on Day 3: 13 - 1 = 12

   Buying on Day 1 and selling on Day 4: 4 - 1 = 3

3. Stock 3 (5):

   Buying on Day 1 and selling on Day 2: 1 - 5 = -4

   Buying on Day 1 and selling on Day 3: 13 - 5 = 8

   Buying on Day 1 and selling on Day 4: 4 - 5 = -1

4. Stock 4 (3):

   Buying on Day 1 and selling on Day 2: 4 - 3 = 1

   Buying on Day 1 and selling on Day 3: 13 - 3 = 10

   Buying on Day 1 and selling on Day 4: 4 - 3 = 1

5. Stock 5 (6):

   Buying on Day 1 and selling on Day 2: 3 - 16 = -13

   Buying on Day 1 and selling on Day 3: 4 - 16 = -12

   Buying on Day 1 and selling on Day 4: 8 - 16 = -8

**Step 3:** Identify the day with the highest potential profit for each stock. In other words, find the maximum potential profit and its corresponding day for each stock.

6. Stock 1 (12):

   **Maximum Potential Profit**: 3 (Days 2, 3, and 4)

7. Stock 2 (1):

   **Maximum Potential Profit:** 12 (Day 4)

8. Stock 3 (4):

   **Maximum Potential Profit**: 13 (Day 2)

9. Stock 4 (4):

   **Maximum Potential Profit**: 9 (Day 4)

10. Stock 5 (6):

    **Maximum Potential Profit**: 5 (Day 3)

**Step 4:** Determine the stock and day combination that yields the maximum potential profit. Select the stock and the day for that stock where the maximum potential profit was found.

11. Maximum Profit:

    **Stock**: 3

    **Day**: 2

    **Maximum Potential Profit:** 13

    So, the maximum profit achievable through a single transaction is 13, which can be obtained by buying Stock 3 on Day 1 and selling it on Day 2.

**Problem 2 Solution:**

**Input Matrix A:**

$$A=\begin{bmatrix} 25 & 30 & 15 & 40 & 50 \\ 10 & 20 & 30 & 25 & 5 \\ 30 & 45 & 35 & 10 & 15 \\ 5 & 50 & 35 & 25 & 45 \end{bmatrix}$$

**Step 1:** Begin with the input matrix A as provided.

**Step 2:** Determine the sequence of at-most K non-overlapping transactions. A valid transaction is a buy-sell of the same stock. Different transactions can have different stocks, but one transaction would deal with only a single stock.

To find the sequence of at-most 5 transactions with maximum profit, we need to consider the potential profits for each stock on each day and select the highest potential profits.

**Calculate the potential profits for each stock:**

12. Stock 1 (25):

    Potential Profits: [0, 5, 10, 25, 25]

13. Stock 2 (30):

    Potential Profits: [0, 0, 15, 10, 20]

14. Stock 3 (15):

    Potential Profits: [0, 0, 0, 25, 10]

15. Stock 4 (40):

    Potential Profits: [0, 0, 0, 0, 40]

16. Stock 5 (50):

    Potential Profits: [0, 0, 0, 0, 0]

**Step 3:** Output a sequence of at-most K transactions in the format of (i, j, l) that yields the maximum potential profit by selling ith stock on the 7th day that was bought on the jth day.

Select the top 5 transactions with the highest potential profits:

1. **Transaction:** (4, 1, 4) - Buying Stock 4 on Day 1 and selling it on Day 4.
2. **Transaction**: (1, 1, 4) - Buying Stock 1 on Day 1 and selling it on Day 4.
3. **Transaction**: (1, 2, 5) - Buying Stock 1 on Day 2 and selling it on Day 5.
4. **Transaction**: (2, 3, 3) - Buying Stock 2 on Day 3 and selling it on Day 3.
5. **Transaction:** (1, 1, 3) - Buying Stock 1 on Day 1 and selling it on Day 3.

These transactions yield the maximum potential profit, and you can perform these transactions to maximize profit. This is the solution to Problem-2 for the given input matrix A and k = 5.

**Problem 3 Solution:**

**Input Matrix A:**

$$A=\begin{bmatrix} 7 & 1 & 5 & 3 & 6 & 8 & 9 \\ 2 & 4 & 3 & 7 & 9 & 1 & 8 \\ 15 & 8 & 9 & 1 & 2 & 3 & 10 \\ 9 & 3 & 4 & 8 & 7 & 4 & 1 \\ 3 & 1 & 5 & 8 & 9 & 6 & 4 \end{bmatrix}$$

**Step 1:** Begin with the input matrix A and integer c = 2 as provided.

**Step 2:** Calculate Maximum Prices to Sell a Stock Bought on Day j

For each day j, we'll identify the maximum price after c + 1 days (i.e., on day j + c + 1 or later) to sell the stock:

1. Day 1 (Buy Stock 1):

   Maximum price to sell is on Day 4: 36

2. Day 2 (Buy Stock 1):

   Maximum price to sell is on Day 4: 36

3. Day 3 (Buy Stock 2):

   Maximum price to sell is on Day 6: 10

4. Day 4 (Buy Stock 3):

   Maximum price to sell is on Day 6: 10

5. Day 5 (Buy Stock 4):

   Maximum price to sell is on Day 7

**Step 3:** Determine the sequence (i, j, l) that yields the maximum potential profit by selling the ith stock on the Ith Day that was bought on jth day.

The sequence that yields the maximum potential profit is (19, 17, 20), which means:

Buy Stock 19 on Day 17 and sell it on Day 20.

This trade results in a maximum potential profit.

So, the maximum profit achievable under the given trading restrictions is obtained by buying Stock 19 on Day 17 and selling it on Day 20.

# Milestone 2

## Task One:

Design a brute force algorithm for solving Problem 1 that runs in O(m * n^2) time.

1. **Programming Language**: Python
2. **Assumptions**:
    - The input matrix is well-formed with no irregularities such as mismatched row sizes or non-integer values.
    - Stock prices are all non-negative integers.
    - The input matrix will not be empty.
3. **Definitions**:
    - **matrix**: A list of lists in Python, where each sublist represents a stock and contains the prices of that stock for consecutive days.
    - **max_profit_info**: A tuple that holds the best transaction details including the stock index (1-indexed), the buy day (1-indexed), the sell day (1-indexed), and the maximum profit found.
    - **stock_index**: An integer representing the index of the current stock in the iteration, starting from 0 for the first stock.
    - **prices**: A list of integers representing the prices of a stock over a series of days.
    - **max_profit**: An integer representing the maximum profit found for a particular stock, initialized to 0 for each new stock in the iteration.
    - **buy_day** and **sell_day**: Integers representing the days on which buying and selling would result in the **max_profit**, respectively. Initialized to 0 and updated within the nested loop when a profitable pair is found.
4. **Pseudocode:**

```
# Function to calculate the maximum profit by comparing all possible buy-sell pairs
Function find_max_profit_brute_force takes a matrix of stock prices:
    # Initialize a tuple to store the best transaction details
    Initialize max_profit_info to (0, 0, 0, 0)  // This holds the stock index, buy day, sell day, and max profit

    # Iterate over each stock using its index and price list
    For each stock_index and prices list in the matrix:
        # Start with no profit as we haven't compared any prices yet
        Initialize max_profit for this stock to 0
        # Default buy day is set to zero, to be updated when a profitable buy day is found
        Initialize buy_day to 0
        # Default sell day is set to zero, to be updated when a profitable sell day is found
        Initialize sell_day to 0

        # Nested loop to compare every possible buy-sell pair of days
        For each day i in the range of prices:
            # Start from the next day (i+1) since you cannot sell on the same day you buy
        For each day j from i+1 to the end of prices:
          # Calculate profit if you were to buy on day i and sell on day j
          Calculate current_profit as the difference between prices[j] (sell price) and prices[i] (buy price)

          # Check if the calculated profit is greater than the previously recorded max profit
          If current_profit is greater than max_profit:
            # Update max_profit with the new maximum
            Set max_profit to current_profit
            # Record the day you should buy to achieve this profit
            Set buy_day to i + 1  // Add 1 to convert from 0-indexed to 1-indexed format
            # Record the day you should sell to achieve this profit
            Set sell_day to j + 1 // Add 1 for the same reason

      # After evaluating all buy-sell pairs for this stock,
      # check if the best profit from this stock beats the best profit from previous stocks
      If max_profit for the current stock is greater than the max_profit stored in max_profit_info:
        # Update max_profit_info with new best transaction details
        Update max_profit_info with (stock_index + 1, buy_day, sell_day, max_profit)

    # After checking all stocks, return the details of the transaction that yields the maximum profit
    Return max_profit_info
```

## Task Two:

Design a greedy algorithm for solving Problem 1 that runs in O(m * n) time.

**1) Programming Language**: Python

**2) Assumptions:**

- The input matrix is a list of lists without any irregularities such as mismatched row sizes or non-integer values.
- All stock prices are non-negative integers.
- The input matrix will not be empty and will contain at least one list with at least two price entries, to allow for a purchase and a sale.

**3) Definitions:**

- **matrix**: A list of lists in Python, where each sublist represents a stock and contains the prices of that stock for consecutive days.
- **max_profit_info**: A tuple that holds the best transaction details, including the stock index (1-indexed), the buy day (1-indexed), the sell day (1-indexed), and the maximum profit found.
- **stock_index**: An integer representing the index of the current stock in the iteration, starting from 0 for the first stock.
- **prices**: A list of integers representing the prices of a stock over a series of days.
- **min_price**: An integer representing the minimum stock price encountered so far for the current stock in the iteration.
- **max_profit**: An integer representing the maximum profit found for a particular stock, initialized to 0 for each new stock in the iteration.

- **buy_day** and **sell_day**: Integers representing the days on which buying and selling would result in the **max_profit**, respectively. Initialized to 1 (considering 1-indexing) and updated within the loop when a new minimum price is found or a higher profit is calculated.
- **current_day**: An integer representing the index of the current day in the iteration, starting from 0 for the first day.
- **price**: An integer representing the current day's price of a stock.
- **current_profit**: An integer calculated as the difference between the current **price** and **min_price**, representing the potential profit if the stock were sold on the current day.

**4) Pseudocode:**

```
Function find_max_profit_greedy_approach takes a matrix of stock prices:
  # Initialize a tuple to store the maximum profit information found so far
  Initialize max_profit_info to (0, 0, 0, 0)  // This will hold the best stock index, buy day, sell day, and max
profit

  # Iterate over each stock along with its daily prices
  For each stock_index and prices list in the matrix:
    # Assume the minimum price is the first price of the stock
    Set min_price to the first price in prices
    # Start with a maximum profit of zero since we haven't calculated profit yet
    Initialize max_profit to 0
    # Assume the best day to buy is the first day, starting at 1 since we're using 1-indexing
    Initialize buy_day to 1
    # Assume the best day to sell is the first day, same reasoning as buy_day
    Initialize sell_day to 1

    # Loop through each price for the current stock
    For each current_day and price in prices:
      # Check if the current price is lower than the previously found minimum price
      If price is less than min_price:
        # If a new minimum is found, update min_price
        Update min_price to the current price
        # Also, update the buy_day since we found a cheaper price to buy at
        Update buy_day to current_day + 1  // Convert from 0-indexed to 1-indexed

      # Calculate the profit if we sold the stock on the current day
      Calculate current_profit as price minus min_price

      # Check if selling today is better than any previous sell day
      If current_profit is greater than max_profit:
        # If so, update max_profit to the current_profit
        Update max_profit to current_profit
        # Update the sell_day to the current day
        Update sell_day to current_day + 1  // Convert from 0-indexed to 1-indexed

    # After processing all prices for the current stock,
    # check if the profit from this stock is better than the profit from previous stocks
    If max_profit for the current stock is greater than the max_profit in max_profit_info:
      # If it is, update max_profit_info with the new best profit information
      Update max_profit_info with the current stock_index + 1, buy_day, sell_day, and max_profit

  # After going through all the stocks, return the information about the stock that gives the maximum profit
```

```
Return max_profit_info
```

**Task Three:**

Design a dynamic programming algorithm for solving Problem 1 that runs in O(m*n)

time.

**Programming Language**: Python
**Assumptions:**

- The list of prices represents the stock prices for a series of consecutive days.
- The prices are non-negative integers.
- The list will contain at least two price entries if it's not empty, to allow for a potential purchase and sale.
- The function is designed to find the best single transaction (one buy followed by one sell) to maximize profit.

**Definitions:**

- **prices**: A list of integers where each integer represents the stock price on a given day.
- **n**: An integer representing the number of days for which we have stock prices.
- **dp**: A list of integers with length **n**, initialized with zeros; it is used to keep track of the maximum profit that can be made ending on day **i**.
- **buy_day**: A list of integers with length **n**, initialized with zeros; it stores the day indices for buying that lead to the maximum profit ending on day **i**.
- **sell_day**: A list of integers with length **n**, initialized with zeros; it stores the day indices for selling that lead to the maximum profit ending on day **i**.
- **min_price**: An integer representing the lowest stock price encountered so far in the iteration.
- **min_price_day**: An integer representing the day index (0-indexed) on which the **min_price** occurred.
- **profit**: An integer representing the potential profit that could be made if the stock were sold on the current day.
- **max_profit_info**: A tuple that will hold the final result, containing the index of the best stock (1-indexed), the best day to buy (1-indexed), the best day to sell (1-indexed), and the maximum profit that can be achieved with a single buy-sell transaction.
- **matrix A**: A matrix (list of lists) where each sublist represents a series of stock prices for a particular stock.
- **index**: An integer representing the current stock's index in the outer loop iterating through **matrix A**.

**Pseudocode:**

```
Function find_max_profit_dp takes a list of prices:
    # If there are no prices, we can't make a profit
    If prices list is empty:
        Return (0, 0, 0)

    # Get the number of days for which we have prices
    Set n to the length of prices
    # If there is only one day's price, we can't make a profit because we can't sell
    If n is less than 2:
        Return (0, 0, 0)

    # Initialize arrays to keep track of the maximum profit and the corresponding buy and sell days
    Initialize dp array with length n filled with zeros
    Initialize buy_day array with length n filled with zeros
    Initialize sell_day array with length n filled with zeros

    # There is no profit to be made on the first day as we can only buy
    Set dp[0] to 0
    # The minimum price and its day are initially set to the first day's price and day
    Set min_price to prices[0]
    Set min_price_day to 0

    # Loop through each day to calculate the maximum profit
    For i from 1 to n-1:
        # If the current day's price is lower than the minimum price found so far, update the minimum
price and its day
        If prices[i] is less than min_price:
            Set min_price to prices[i]
            Set min_price_day to i

        # Calculate potential profit if we sell on the current day
        Calculate profit as prices[i] minus min_price

        # If the potential profit is greater than the profit so far, update the dp array and the corresponding
buy and sell days
        If profit is greater than dp[i-1]:
            Set dp[i] to profit
            Set buy_day[i] to min_price_day
            Set sell_day[i] to i
        # Otherwise, we carry forward the profit and days from the previous day
        Else:
            Set dp[i] to dp[i-1]
            Set buy_day[i] to buy_day[i-1]
            Set sell_day[i] to sell_day[i-1]

    # The last element in the dp array will contain the maximum profit. We return this along with the
buy and sell days (+1 to adjust for 0-indexing)
    Return dp[n-1], buy_day[n-1] + 1, sell_day[n-1] + 1
```

```
# Given a matrix A of stock prices for various stocks
Define a matrix A with lists of stock prices

# Initialize variable to store the best stock index, buy day, sell day, and the max profit
Initialize max_profit_info to (0, 0, 0, 0)

# Loop through each stock's prices in the matrix
For each index and prices list in matrix A:
  # Find the max profit for the current list of prices using the DP function
  Call find_max_profit_dp with prices
  # If the calculated profit is greater than the max profit stored in max_profit_info, update it
  If max_profit from find_max_profit_dp is greater than the fourth element in max_profit_info:
    Update max_profit_info with index+1 (for 1-based indexing), buy_day, sell_day, and max_profit

# Output the result with the best stock to buy, the day to buy, the day to sell, and the max profit
Print "Stock to choose:", max_profit_info[0], "Buy on day:", max_profit_info[1], "Sell on day:",
max_profit_info[2], "Max profit:", max_profit_info[3]
```

**Task Four**

Design a dynamic programming algorithm for solving Problem 2 that runs in O(m * n^2k) time.

**Programming Language**: Python

***Variables and Definitions:***

- *allTransactions:* A list designed to record the sequence of transactions that culminate in the highest possible profit.
- *DP[i][j][t]:* A 3D array that represents the maximum attainable profit from trading, where the first dimension corresponds to different stocks, the second to consecutive being trading days, and the third is the number of transactions completed.

***Pseudo Code***:

```
function findMaxProfit(A, k):
    m, n = dimensions of A
    maxProfit = 0
```

```
                bestTransaction = []
        function calculateProfit(transactions):
                profit = 0
                for transaction in transactions:
                i, buyDate, sellDate = transaction
                profit += A[i][sellDate] - A[i][buyDate]
    return profit
function tryTransactions(currTransaction, lastSellDate, numTransactions):
    if numTransactions == k:
        profit = calculateProfit(currTransaction)
        if profit > maxProfit:
            maxProfit = profit
            bestTransaction = list(currTransaction)
        return
    for i from 0 to m-1:
        for buyDate from lastSellDate+c+1 to n-1:
            for sellDate from buyDate+1 to n:
                currTransaction.append((i, buyDate, sellDate))
                tryTransactions(currTransaction, sellDate, numTransactions + 1)
                currTransaction.pop()
tryTransactions([], -c-1, 0)


return (maxProfit, bestTransaction)
```

**Task Five**

Design a dynamic algorithm for solving Problem 2 that runs in O(m * n * k) time.

**Programming Language**: Python

***Variable and Definitions:***

- *DP[t][i][j]:* A 3D array where each entry captures the highest profit achievable.
- *maxDifference:* A 3D array to store the max difference of the stock price.
- *allTransactions:* A list of all the transactions.

***Pseudo Code:***

```
function findMaxProfit(A, c, k):
        m, n = dimensions of A
        DP = 3D array of dimensions k+1 * m * n, initialized to 0
        maxDifference = 3D array of dimensions k+1 * m * n, initialized to -infinity for t
> 0
  transactions = empty list
  for t from 0 to k:
    for i from 0 to m-1:
      for j from 0 to n-1:
        DP[t][i][j] = 0 if t == 0 else -infinity
        maxDifference[t][i][j] = -infinity if t > 0 else 0
  for t from 1 to k:
    for i from 0 to m-1:
      for j from 1 to n-1:
        if j > c:
          maxDifference[t][i][j-c-1] = max(maxDifference[t][i][j-c-2], DP[t-1][i][j-c-1] -
A[i][j-c-1])
```

```
            DP[t][i][j] = max(DP[t][i][j-1], A[i][j] + maxDifference[t][i][j-c-1])
            if DP[t][i][j] > DP[t][i][j-1] and j > c:
                transactions.append((i, j-c-1, j))
    maxProfit = max(DP[k][i][n-1] for i in range(m))
    finalTransactions = extractTransactions(transactions, DP, k, maxProfit)

    return (maxProfit, finalTransactions)
```

## Milestone 3

**Task One:**

Design a brute force algorithm for solving Problem 1 that runs in O(m * n^2) time.

**Code:**

```
def find_max_profit_brute_force(matrix):
    max_profit_info = (0, 0, 0, 0)  # (stock_index, buy_day, sell_day, max_profit)

    # Iterate through each stock
    for stock_index, prices in enumerate(matrix):
        # Initialize max_profit for this stock
        max_profit = 0
        buy_day = 0
        sell_day = 0

        # Iterate through each day to buy
        for i in range(len(prices)):
            # Iterate through each day to sell
            for j in range(i+1, len(prices)):
                # Calculate the profit
                current_profit = prices[j] - prices[i]
                # Update max_profit if the current_profit is greater
                if current_profit > max_profit:
                    max_profit = current_profit
                    buy_day = i + 1  # +1 to convert from 0-indexed to 1-indexed
                    sell_day = j + 1  # +1 to convert from 0-indexed to 1-indexed

        # Update the max_profit_info if the current stock's max profit is greater than the previous
max profit
        if max_profit > max_profit_info[3]:
            max_profit_info = (stock_index + 1, buy_day, sell_day, max_profit)

    return max_profit_info

# Given input matrix A
A = [
    [7, 1, 5, 3, 6 ],
    [2, 4, 3, 7, 9],
    [5, 8, 9, 1, 2],
    [9, 3, 14, 8, 7]
]
```

```
# Find the stock with the maximum profit using the brute force approach
result = find_max_profit_brute_force(A)


# Print the result
print(f"Stock to choose: {result[0]}, Buy on day: {result[1]}, Sell on day: {result[2]}, Max
profit: {result[3]}")
print(f"The final output for the given matrix should be: [{result[0]}, {result[1]}, {result[2]},
{result[3]}]")
#expected result: Stock to choose: 4, Buy on day: 2, Sell on day: 3, Max profit: 11
#expected result: The final output for the given matrix should be: [4, 2, 3, 11]
```

**Task Two:**

Design a greedy algorithm for solving Problem 1 that runs in O(m * n) time.

**Code:**

```
def find_max_profit_greedy_approach(matrix):
  max_profit_info = (0, 0, 0, 0)  # (stock_index, buy_day, sell_day, max_profit)


  # Iterate through each stock
  for stock_index, prices in enumerate(matrix):
    min_price = prices[0]
    max_profit = 0
    buy_day = 1
    sell_day = 1
```

```
        # Iterate through the days for each stock
        for current_day, price in enumerate(prices):
            # Check if current price is less than minimum price found so far
            if price < min_price:
                min_price = price
                buy_day = current_day + 1  # +1 to convert from 0-indexed to 1-indexed

            # Calculate profit if we sell on the current day
            current_profit = price - min_price

            # Check if current calculated profit is greater than the max profit so far
            if current_profit > max_profit:
                max_profit = current_profit
                sell_day = current_day + 1  # +1 to convert from 0-indexed to 1-indexed

        # Update the max_profit_info if the current stock's max profit is greater than the previous
max profit
        if max_profit > max_profit_info[3]:
            max_profit_info = (stock_index + 1, buy_day, sell_day, max_profit)

    return max_profit_info

# Given input matrix A
A = [
    [7, 1, 5, 3, 6 ],
    [2, 4, 3, 7, 9],
    [5, 8, 9, 1, 2],
    [9, 3, 14, 8, 7]
]
# Find the stock with the maximum profit
result = find_max_profit_greedy_approach(A)


# Print the result
print(f"Stock to choose: {result[0]}, Buy on day: {result[1]}, Sell on day: {result[2]}, Max
profit: {result[3]}")
print(f"The final output for the given matrix should be: [{result[0]}, {result[1]}, {result[2]},
{result[3]}]")


#expected output: Stock to choose: 4, Buy on day: 2, Sell on day: 3, Max profit: 11
```

**Task Three:**

Design a dynamic programming algorithm for solving Problem 1 that runs in O(m*n) time.

**Code:**

```
def find_max_profit_dp(prices):
    # If there are no prices, return zeros for profit, buy day, and sell day
    if not prices:
        return (0, 0, 0)


    n = len(prices)
```

```
# If there is only one day's price, no profit can be made

if n < 2:

    return (0, 0, 0)


# Initialize arrays to store max profit, and the corresponding buy and sell days

dp = [0] * n

buy_day = [0] * n

sell_day = [0] * n


# Initialize the minimum price and its day to the first day

min_price = prices[0]

min_price_day = 0


# Iterate over the price list

for i in range(1, n):

    # Update minimum price and its day if a lower price is found

    if prices[i] < min_price:

        min_price = prices[i]

        min_price_day = i


    # Calculate the profit if sold on the current day

    profit = prices[i] - min_price


    # Update the dp array with the maximum profit up to the current day

    if profit > dp[i-1]:
            dp[i] = profit
            buy_day[i] = min_price_day
            sell_day[i] = i
        else:
            dp[i] = dp[i-1]
            buy_day[i] = buy_day[i-1]
            sell_day[i] = sell_day[i-1]

    # Return the maximum profit and the corresponding buy and sell days
    # (+1 for 1-indexing, as day 0 in the array is day 1 in real-world terms)
    return (dp[n-1], buy_day[n-1] + 1, sell_day[n-1] + 1)

# Example usage

# Define a matrix A with lists of stock prices for different stocks
A = [
    [7, 1, 5, 3, 6 ],
    [2, 4, 3, 7, 9],
    [5, 8, 9, 1, 2],
    [9, 3, 14, 8, 7]
]

# Initialize variable to store the best stock index, buy day, sell day, and the max profit
max_profit_info = (0, 0, 0, 0)
```

```
 # Loop through each stock's prices in the matrix
 for index, prices in enumerate(A):
     max_profit, buy_day, sell_day = find_max_profit_dp(prices)
     # Update max_profit_info if the current stock yields a higher profit
     if max_profit > max_profit_info[3]:
         max_profit_info = (index + 1, buy_day, sell_day, max_profit)

 # Output the result
 print("Stock to choose:", max_profit_info[0],
       "Buy on day:", max_profit_info[1],
       "Sell on day:", max_profit_info[2],
       "Max profit:", max_profit_info[3])

 #Expected result: Stock to choose: 4 Buy on day: 2 Sell on day: 3 Max profit: 11
```

**Task Four**

Design a dynamic programming algorithm for solving Problem 2 that runs in O(m * n^2k) time.

**Code:**

```
def findMaxProfit(A, k, c):
   # m: number of stocks, n: number of days
   m, n = len(A), len(A[0])

   # Initialize max profit and best transaction sequence variables
```

```
    maxProfit = 0
    bestTransaction = []

# Calculate total profit from a series of transactions
    def calculateProfit(transactions):
        profit = 0
        for transaction in transactions:
            i, buyDate, sellDate = transaction
            profit += A[i][sellDate] - A[i][buyDate]
        return profit

    # Recursive function to try all possible transaction combinations
    def tryTransactions(currTransaction, lastSellDate, numTransactions):
        nonlocal maxProfit, bestTransaction

        #  calculate profit if transaction count equals k
        if numTransactions == k:
            profit = calculateProfit(currTransaction)
            if profit > maxProfit:
                maxProfit = profit
                bestTransaction = list(currTransaction)
            return

        # loop over each stock and all potential buy/sell dates
        for i in range(m):
            for buyDate in range(lastSellDate + c + 1, n - 1):
                for sellDate in range(buyDate + 1, n):
                    currTransaction.append((i, buyDate, sellDate))
                    tryTransactions(currTransaction, sellDate, numTransactions + 1)
                    currTransaction.pop()

    # begin transaction process with no initial transactions
    tryTransactions([], -c - 1, 0)

    # return max profit based on best transation
     return maxProfit, bestTransaction
```

**Task Five**

Design a dynamic algorithm for solving Problem 2 that runs in O(m * n * k) time.

**Code:**

```
def findMaxProfit(A, c, k):
# calculate the sizes of rows and columns in the matrix A
    m, n = len(A), len(A[0])
    DP = np.zeros((k + 1, m, n))  # initialize DP
    maxDifference = np.full((k + 1, m, n), float('-inf'))
#initialize transaction list
    transactions = []
    for t in range(k + 1):
        for i in range(m):
            for j in range(n):
                if t == 0:
                    DP[t][i][j] = 0
                else:
                    maxDifference[t][i][j] = float('-inf')
    # calculate max profit
    for t in range(1, k + 1):
        for i in range(m):
            for j in range(1, n):
                if j > c:
                    prev_max_diff = float('-inf') if j - c - 2 < 0 else maxDifference[t][i][j - c - 2]
                    maxDifference[t][i][j - c - 1] = max(prev_max_diff, DP[t - 1][i][j - c - 1] - A[i][j - c -
1])
                DP[t][i][j] = max(DP[t][i][j - 1], A[i][j] + maxDifference[t][i][j - c - 1])
                # Log transaction if it leads to an increase in profit
                if DP[t][i][j] > DP[t][i][j - 1] and j > c:
                    transactions.append((i, j - c - 1, j))

    # find max profit from all transactions
    maxProfit = max(DP[k, i, n - 1] for i in range(m))
    # get transaction that equaled to max profit
    finalTransactions = extractTransactions(transactions, DP, k, m, n)
    return maxProfit, finalTransactions
```

```
#method for extracting transactions to help find maxProfit
def extractTransactions(transactions, DP, k, m, n):
   finalTransactions = []
#get max profit from DP
   maxProfit = DP[k][m - 1][n - 1]

   # loop in reverse over the transaction count
   for t in reversed(range(1, k + 1)):
      # loop backwards through list of transaction
      for transaction in reversed(transactions):
         i, j_start, j_end = transaction
         # check if transactions adds to max profit
         if DP[t][i][j_end] == maxProfit:
            finalTransactions.append(transaction)
            # subtract profit from max profit
            maxProfit -= A[i][j_end] + maxDifference[t][i][j_end - c - 1]
            break

   return finalTransactions
```