Project Milestone 1

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Project

GitHub Repository Link
Communication method: Discord
Member Roles: Daniel De Oliveira (Problem 1), K. Anjuli Jones (Problem 2), Matthew Dam (Problem 3)
Project Gantt Chart: (including internal deadlines and meetings)

Milestone 1: Understanding the Problem

Problem 1

Step 1. Input matrix A

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

Step 2. Potential profit by selling on each day for each stock.

Let $p_{i,j}$ be the potential profit of selling stock i on day j. Then,

- $p_{1,1} = 0$, $p_{1,2} = 0$, $p_{1,3} = 4$, $p_{1,4} = 2$, $p_{1,5} = 15$
- $p_{2,1} = 0$, $p_{2,2} = 0$, $p_{2,3} = 9$, $p_{2,4} = 0$, $p_{2,5} = 5$
- $p_{3,1} = 0$, $p_{3,2} = 2$, $p_{3,3} = 0$, $p_{3,4} = 0$, $p_{3,5} = 1$
- $p_{4,1} = 0$, $p_{4,2} = 0$, $p_{4,3} = 1$, $p_{4,4} = 5$, $p_{4,5} = 7$

Step 3. Identify the day with the highest potential profit for each stock.

Based on the calculated values for $p_{i,j}$ in the previous step,

- $max_j p_{1,j} = 15$, on day 5
- $max_j p_{2,j} = 9$, on day 3
- $max_j p_{3,j} = 2$, on day 2
- $max_j p_{4,j} = 7$, on day 5

Step 4. Determine the stock and day combination that yields the maximum potential profit.

Based on step 3, the maximum potential profit is 15 and is obtained by selling the first stock on the fifth day. The stock would be bought on the second day, therefore the output for this example would be

$$(1, 2, 5, 15)$$

Problem 2

You are given a matrix A of dimensions $m \times n$, where each element represents the predicted prices of m different stocks for n consecutive days. Additionally, you are given an integer $k(1 \leq k \leq n)$. Your task is to find a sequence of at most k transactions, each involving the purchase and sale of a single stock, that yields the maximum profit.

Input:

- A matrix A of dimensions $m \times n(1 \leq m, n \leq 1000)$, where each element $A[i][j](0 \leq A[i][j] \leq 105)$ represents the predicted price of the i-th stock on the j-th day.
- An integer $k(1 \leq k \leq n)$ representing the maximum number of transactions allowed.

Output:

Return a sequence of tuples (i, j_1, j_2) representing the transactions where:

- $i(1 \leq i \leq m)$ is the index of the chosen stock.
- $j_1(1 \leq j_1 \leq n)$ is the day when you would buy the stock to maximize profit in this transaction.
- $j_2(1 \leq j_2 \leq n)$ is the day when you would sell the stock to maximize profit in this transaction.

Contstraints:

- You can perform at most k transactions, each involving the purchase and sale of a single stock.
- You must buy before selling; in other words, j_1 must be less than j_2.
- The prices are non-negative integers and represent the stock's value at a specific time.
- You want to maximize profit, so you're looking for the highest possible difference between the sell price and the buy price.
- If no profitable transaction is possible, return an empty sequence. If there are multiples sequences achieving the same optimal profit, return any one of them.

Example:

Input:

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

$$k = 3$$

Output:

$$[(2, 1, 2), (1, 2, 3), (2, 3, 5)]$$

Explanation Performing at most 3 transactions, selling the 2nd stock on the 2nd day after buying on 1st day, 1st stock selling on the 3rd day buying on 2nd day, 2nd stock selling on 5th day buying on 3rd day yields the maximum profit of 17 (transaction 1: $9 - 2 = 7$, transaction 2: $5 - 1 = 4$, transaction 3: $9 - 3 = 6$).

Note: In each transaction tuple (i, j_1, j_2), the buy day j_1 is strictly less than the sell day j_2. However, when comparing different transactions, we do not consider them overlapping as along as the actual days involved do not conflict. For example, $(1, 2)$ and $(2, 3)$ are not considered as overlapping because the sell day of the first is the same as the buy day of the second. Similarly, $(2, 3)$ and $(3, 5)$ are valid together. But if it is $(2, 4)$ and $(3, 5)$, then we consider them as overlapping.

Work out the given numerical example for Problem-2. That is, you are given a matrix A of dimensions $m \times n$, where each element represents the predicted prices of m different stocks for n consecutive days. Additionally, you are given an integer $k (1 \leq k \leq n)$. Your task is to manually find a sequence of at most k transactions, each involving the purchase and sale of a single stock, that yields the maximum profit.

Input Matrix A

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

$$k = 3$$

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

We start with 4 stocks, 5 days, and a maximum of 3 transactions that cannot overlap.

Step 2. Identify maximum profits for each stock
This step can be completed by

Stock 1

1. Buy $[Stock_1, Day_1] = 25$, Sell $[Stock_1, Day_2] = 30$, profit $= 5$
2. Buy $[Stock_1, Day_1] = 25$, Sell $[Stock_1, Day_3] = 15$, profit $=$ loss
3. Buy $[Stock_1, Day_1] = 25$, Sell $[Stock_1, Day_4] = 40$, profit $= 15$
4. Buy $[Stock_1, Day_1] = 25$, Sell $[Stock_1, Day_5] = 50$, profit $= 25$
5. Buy $[Stock_1, Day_2] = 30$, Sell $[Stock_1, Day_3] = 15$, profit $=$ loss
6. Buy $[Stock_1, Day_2] = 30$, Sell $[Stock_1, Day_4] = 40$, profit $= 10$
7. Buy $[Stock_1, Day_2] = 30$, Sell $[Stock_1, Day_5] = 50$, profit $= 20$
8. Buy $[Stock_1, Day_3] = 15$, Sell $[Stock_1, Day_4] = 40$, profit $= 25$
9. Buy $[Stock_1, Day_3] = 15$, Sell $[Stock_1, Day_5] = 50$, profit $= 35$
10. Buy $[Stock_1, Day_4] = 40$, Sell $[Stock_1, Day_5] = 50$, profit $= 10$

Maximum profits for stock 1

1. Buy $[Stock_1, Day_1] = 25$, Sell $[Stock_1, Day_4] = 40$, profit $= 15$
2. Buy $[Stock_1, Day_1] = 25$, Sell $[Stock_1, Day_2] = 30$, profit $= 5$
3. Buy $[Stock_1, Day_2] = 30$, Sell $[Stock_1, Day_5] = 50$, profit $= 20$
4. Buy $[Stock_1, Day_2] = 30$, Sell $[Stock_1, Day_4] = 40$, profit $= 10$
5. Buy $[Stock_1, Day_3] = 15$, Sell $[Stock_1, Day_4] = 40$, profit $= 25$
6. Buy $[Stock_1, Day_3] = 15$, Sell $[Stock_1, Day_5] = 50$, profit $= 35$
7. Buy $[Stock_1, Day_4] = 40$, Sell $[Stock_1, Day_5] = 50$, profit $= 10$

Stock 2

1. Buy $[Stock_2, Day_1] = 10$, Sell $[Stock_2, Day_2] = 20$, profit = 10
2. Buy $[Stock_2, Day_1] = 10$, Sell $[Stock_2, Day_3] = 30$, profit = 20
3. Buy $[Stock_2, Day_1] = 10$, Sell $[Stock_2, Day_4] = 25$, profit = 15
4. Buy $[Stock_2, Day_1] = 10$, Sell $[Stock_2, Day_5] = 5$, profit = loss
5. Buy $[Stock_2, Day_2] = 20$, Sell $[Stock_2, Day_3] = 30$, profit = 10
6. Buy $[Stock_2, Day_2] = 20$, Sell $[Stock_2, Day_4] = 25$, profit = 5
7. Buy $[Stock_2, Day_2] = 20$, Sell $[Stock_2, Day_5] = 5$, profit = loss
8. Buy $Stock_2, Day_3 = 30$, Sell $Stock_2, Day_4 = 25$, profit = loss
9. Buy $Stock_2, Day_3 = 30$, Sell $Stock_2, Day_5 = 5$, profit = loss
10. $Stock_2, Day_4 = 25$, Sell $Stock_2, Day_5 = 5$, profit = loss

Maximum profits for stock 2

1. Buy $[Stock_2, Day_1] = 10$, Sell $[Stock_2, Day_3] = 30$, profit = 20
2. Buy $[Stock_2, Day_1] = 10$, Sell $[Stock_2, Day_4] = 25$, profit = 15
3. Buy $[Stock_2, Day_1] = 10$, Sell $[Stock_2, Day_2] = 20$, profit = 10
4. Buy $[Stock_2, Day_2] = 20$, Sell $[Stock_2, Day_3] = 30$, profit = 10
5. Buy $[Stock_2, Day_2] = 20$, Sell $[Stock_2, Day_4] = 25$, profit = 5

Stock 3

1. Buy $[Stock_3, Day_1] = 30$, Sell $[Stock_3, Day_2] = 45$, profit = 15
2. Buy $[Stock_3, Day_1] = 30$, Sell $[Stock_3, Day_3] = 35$, profit = 5
3. Buy $[Stock_3, Day_1] = 30$, Sell $[Stock_3, Day_4] = 10$, profit = loss
4. Buy $[Stock_3, Day_1] = 30$, Sell $[Stock_3, Day_5] = 15$, profit = loss
5. Buy $[Stock_3, Day_2] = 45$, Sell $[Stock_3, Day_3] = 35$, profit = loss
6. Buy $[Stock_3, Day_2] = 45$, Sell $[Stock_3, Day_4] = 10$, profit = loss
7. Buy $[Stock_3, Day_2] = 45$, Sell $[Stock_3, Day_5] = 15$, profit = loss
8. Buy $[Stock_3, Day_3] = 35$, Sell $[Stock_3, Day_4] = 10$, profit = loss
9. Buy $[Stock_3, Day_3] = 35$, Sell $[Stock_3, Day_5] = 15$, profit = loss
10. Buy $[Stock_3, Day_4] = 10$, Sell $[Stock_3, Day_5] = 15$, profit = 5

Maximum profits for stock 3

1. Buy $[Stock_3, Day_1] = 30$, Sell $[Stock_3, Day_2] = 45$, profit $= 15$
2. Buy $[Stock_3, Day_1] = 30$, Sell $[Stock_3, Day_3] = 35$, profit $= 5$
3. Buy $[Stock_3, Day_4] = 10$, Sell $[Stock_1, Day_5] = 15$, profit $= 5$

Stock 4

1. Buy $[Stock_4, Day_1] = 5$, Sell $[Stock_4, Day_2] = 50$, profit $= 45$
2. Buy $[Stock_4, Day_1] = 5$, Sell $[Stock_4, Day_3] = 35$, profit $= 30$
3. Buy $[Stock_4, Day_1] = 5$, Sell $[Stock_4, Day_4] = 25$, profit $= 20$
4. Buy $[Stock_4, Day_1] = 5$, Sell $[Stock_4, Day_5] = 45$, profit $= 40$
5. Buy $[Stock_4, Day_2] = 50$, Sell $[Stock_4, Day_3] = 35$, profit = loss
6. Buy $[Stock_4, Day_2] = 50$, Sell $[Stock_4, Day_4] = 25$, profit = loss
7. Buy $[Stock_4, Day_2] = 50$, Sell $[Stock_4, Day_5] = 45$, profit = loss
8. Buy $Stock_4, Day_3 = 35$, Sell $Stock_4, Day_4 = 25$, profit = loss
9. Buy $Stock_4, Day_3 = 35$, Sell $Stock_4, Day_5 = 45$, profit $= 10$
10. Buy $Stock_4, Day_4 = 25$, Sell $Stock_4, Day_5 = 45$, profit $= 20$

Maximum profits for stock 4

1. Buy $[Stock_4, Day_1] = 5$, Sell $[Stock_4, Day_2] = 50$, profit $= 45$
2. Buy $[Stock_4, Day_1] = 5$, Sell $[Stock_4, Day_5] = 45$, profit $= 40$
3. Buy $[Stock_4, Day_1] = 5$, Sell $[Stock_4, Day_3] = 35$, profit $= 30$
4. Buy $[Stock_4, Day_1] = 5$, Sell $[Stock_4, Day_4] = 25$, profit $= 20$
5. Buy $Stock_4, Day_4 = 25$, Sell $Stock_4, Day_5 = 45$, profit $= 20$
6. Buy $Stock_4, Day_3 = 35$, Sell $Stock_4, Day_5 = 45$, profit $= 10$
7. Buy $[Stock_2, Day_2] = 20$, Sell $[Stock_2, Day_3] = 30$, profit $= 10$
8. Buy $[Stock_2, Day_2] = 20$, Sell $[Stock_2, Day_4] = 25$, profit $= 5$

Step 3. Output should be 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 lth day that was bought on jth day.

1. We start with our largest profit: Buy $[Stock_4, Day_1] = 5$, Sell $[Stock_4, Day_2] = 50$, profit = 45. (4,1,2)
2. We then find our next largest non-overlapping profit by eliminating all options that include Day 1 as the buying day. Buy $[Stock_1, Day_3] = 15$, Sell $[Stock_1, Day_5] = 50$, profit = 35. (1, 3, 5)
3. We then find our third and last largest non-overlapping profit by eliminating all options that including day 1 and 3 as the buying day and Stock 4 and 1. Buy $[Stock_2, Day_2] = 20$, Sell $[Stock_2, Day_3] = 30$, profit = 10. (2, 2, 3)

This yields a maximum profit of 90

Problem 3

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

$$c = 2$$

Step 1. Begin with the input matrix A and integer c as provided

Step 2. For each day j, identify the maximum price to sell the stock ℓ. You can only buy another stock after $c + 1$ days (i.e., on day $\ell + c + 1$ or later).

Let i = stock number; j = buy day; ℓ = sale day.

1 Buy 1 Sell Combinations

$$\begin{aligned} (1, 2, 7) &: \quad profit = 8 \\ (2, 6, 7) &: \quad profit = 7 \\ (3, 4, 7) &: \quad profit = 9 \\ (4, 2, 4) &: \quad profit = 5 \\ (5, 2, 5) &: \quad profit = 8 \\ &\vdots \end{aligned}$$

2 Buy 2 Sell Combinations

$$
\begin{aligned}
(1,1,2),(1,5,7):&\quad profit=-3\\
(2,1,2),(2,6,7):&\quad profit=5\\
(3,1,2),(3,5,7):&\quad profit=11\\
(4,1,2),(4,6,7):&\quad profit=-9\\
(5,1,2),(5,6,7):&\quad profit=-4\\
&\vdots\\
(1,2,3),(1,6,7):&\quad profit=5\\
(2,1,3),(2,6,7):&\quad profit=8\\
(3,1,3),(3,6,7):&\quad profit=11\\
(4,2,3),(4,6,7):&\quad profit=-2\\
(5,2,3),(5,6,7):&\quad profit=2\\
&\vdots
\end{aligned}
$$

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

Maximum profit found is 11. Therefore, the sequences that yields the maximum potential profit are

$$[(3,1,3),(3,6,7)] \quad \text{and} \quad [(3,1,2),(3,5,7)]\,.$$