Final Project

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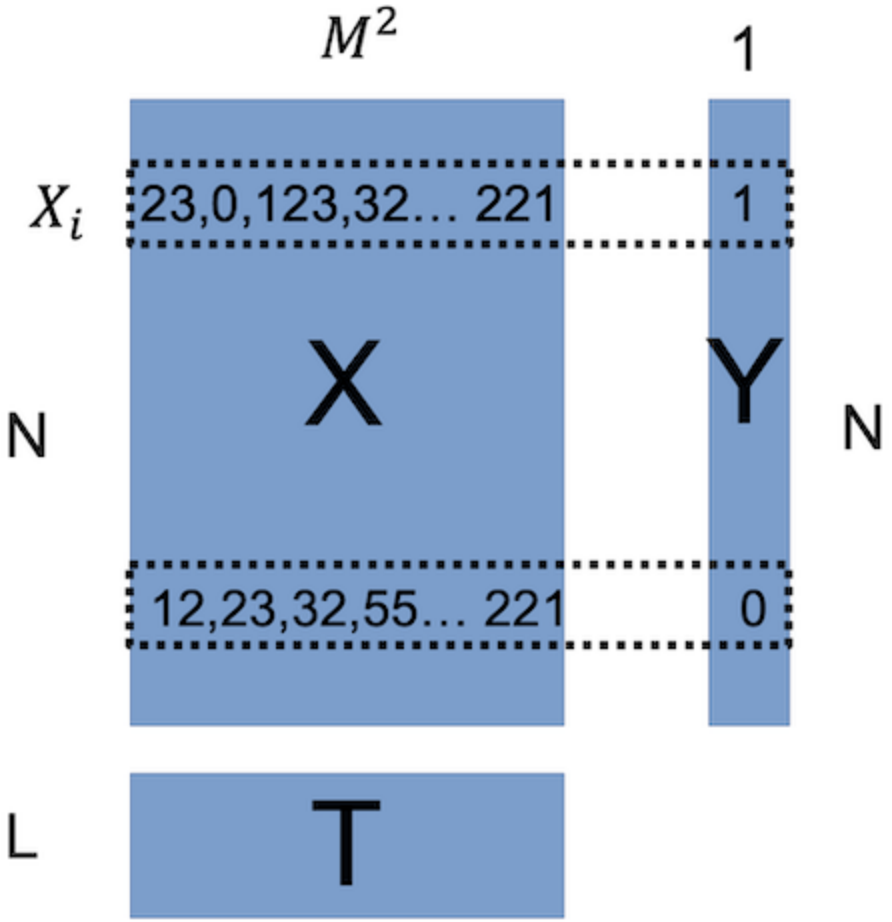
Final Project: "Recognising" Images

- In this final project, you will write a program that "recognises" handwritten digits.
- Given **test images**, your program guesses whether these images are digit "1" or not.
    - The "guessing" is done using the k-nearest neighbours algorithm, a widely known machine learning algorithm.
- This project worth 12.5% of your total score in this unit.
    - You will get a score from 0-100.
- Read the instructions and the skeleton code before you start.

Part I, The Data Set

- The CW folder contains 3 `.matrix` files storing 3 matrices.
  - `X.matrix` stores an N by M^2 matrix X where each row is a grayscale M by M image stored in row-major order.
  - `Y.matrix` stores an N by 1 matrix Y where each row is a scalar, indicating whether the corresponding row in X is digit 1 or not.
  - `T.matrix` stores an L by M^2 matrix T where each row is an M by M **test image** in row major order.
  - X and Y together are called "training set" in machine learning, while T is the "testing set". Y is called the "labels" of X.

Part I, Data Structure



- If $Y_i = 1$, then the image X_i is a handwritten digit 1. If $Y_i \neq 1$, the image X_i is NOT a handwritten digit 1.

Part I, Loading Dataset

- The code for loading these images from files have been provided to you. Matrices are represented by a **matrix structure** in this coursework.

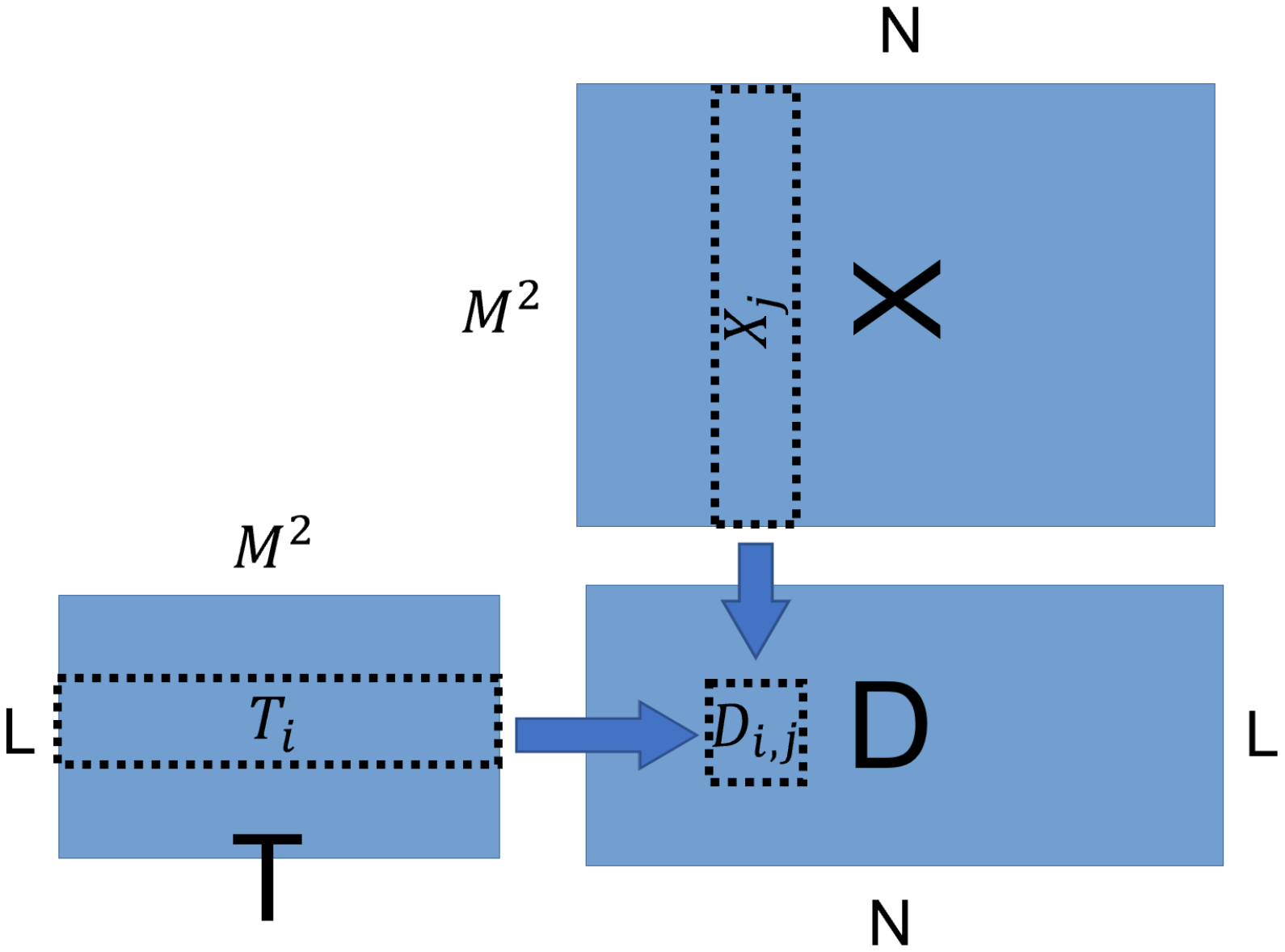
```c
struct matrix
{
    int numrow; //number of rows
    int numcol; //number of columns
    int *elements; // pointer pointing to an integer array
    // storing all entries in the matrix in row major order.
};
typedef struct matrix Matrix;
// now "Matrix" is an alias of "struct matrix"
```

- By simply running the skeleton code, you should see some basic statistics of X, Y and T .
    - What are M, N and L?
    - How many images in the training set X are digit 1?

Part II Computing Distance Matrix D (40pt in total)

- Construct an L by N matrix D, where the i, j-th element $D_{ij} = \mathrm{dist2}(T_i, X_j)$
  - T_i is the i-th row of T.
  - X_j is the j-th row of X
- $\mathrm{dist2}(a, b)$ computes the squared euclidean distance between two vectors a and b with K elements.
  - $\mathrm{dist2}(a, b) := \sum_{k=1}^{K} (a_k - b_k)^2$.

Part II (Computing D)



Part II.1 (15pt) Constructing D

Before your `main` function,

1. Write a few helper functions:

- ```
  int get_elem(Matrix M, int i, int j)
  ```

  returns the `i, j` th element of matrix `M`.

- ```
  void set_elem(Matrix M, int i, int j, int value)
  ```

  assign `value` to the `i, j` th element of matrix `M`
  In this coursework, `i, j` are **zero-based indices**.

In your `main` function,

2. Allocate HEAP memory for D.
3. Declare and initialize a new `matrix` variable `D`.

Part II.2 Computing D (25pt)

Now, populate the matrix D with correct values.

- **Hint**: Compare the computation of D and the matrix multiplication. What are the similarities and what are the dissimilarities?
    - Can you modify the matrix multiplication code to compute matrix D?
- **Hint**, you can write a function

```
void pairwise_dist(Matrix T, Matrix X, Matrix D)
```

    - where D is the output, storing the outcome.
- Partial points will be given for correctly written code for computing $\text{dist2}(a, b)$.

Part III.1 Guessing Labels (15%)

- For each row of matrix D, find **the indices** of the five smallest elements.
  - Suppose the i-th row of D is $[3, 2, 5, 1, 2, 5, 13, 46, 32]$,
  - The indices of the five smallest elements are $[3, 1, 0, 5, 6]$.
  - Hint: Write a helper function

    ```
    void minimum5(int len, int a[], int indices[])
    ```

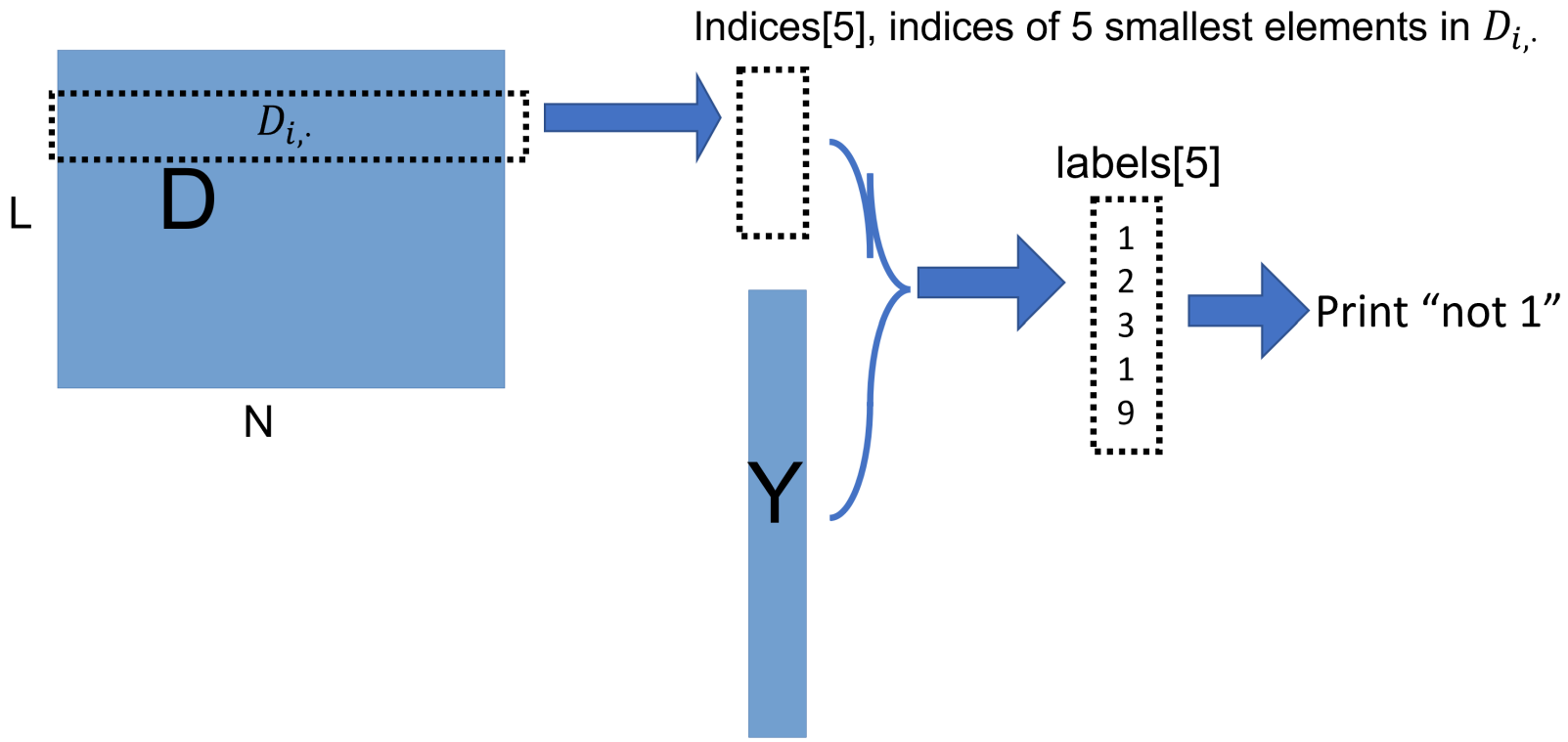
    It takes an array `a` with length `len` as input, then fills `indices[]` with the indices of the five smallest elements.

Part III.2 Guessing Labels (15%)

- Now, suppose the array `indices` contains the indices of the five smallest elements in row i of matrix D.
  - Create a new array `labels` with length 5.
  - Assign the value of $Y_{\text{indices}[k],0}$ to the k-th element in `labels`.
  - Count the number of `1` in `labels`.
  - If the count >= 3, print out `1`. Otherwise, print `not 1`.
- Repeat above for all rows in D.

Part III Guessing Labels (30pts total)

For each row in D, do:



Part III Guessing Labels

- At each row D_i, the print-out is your "guess" of the testing image T_i using 5-nearest neighbour algorithm.
    - If the print-out is `1`, it means the algorithm thinks the image T_i is a digit 1.
    - If the print-out is `not 1`, it means the algorithm thinks the image T_i is NOT a digit 1.
- After your guess, you can optionally print the image stored in T_i to the console to validate your guess.

Part III Guessing Labels

- Hint: Write pseudo code for Part III before writing the real code.
- You might want to test your functions in a separate c file to ensure that they are correctly written.

Final Project: Marking Criteria

- Submitting correct code (10%)
    - Submitting a C file with **the correct name**.
    - Your code compiles and runs **without major error** such as **crash**, **infinite loop**.
        - It will be tested using `gcc` in the lab pack.
- Part II 40% (15% + 25%)
- Part III 30% (15% + 15%)
- Good Coding Practice (20%)
    - Good code format
    - Good variable naming scheme.
    - Apt comments

Final Project: Dos and Don'ts

- You can discuss with your classmates about general strategies but write your own code!
- Don't give your code to other students.
- Review relevant previous lab sessions before you start.
- You can use whatever material you can find to help you complete the task, but you need to add a reference in the comments.
- You are only allowed to use standard features of C.
  - You can use `stdio.h`, `stdlib.h`, `limits.h` and `math.h`.
  - If you want to use other libraries, consult with the lecturer or TA beforehand.

Final Project: Q&A

- We will answer questions posted on the Blackboard forum or answering them during the lab sessions.
- We will inspect the forum regularly and try to respond in 24 hours.