

# Final Project

Song Liu ([song.liu@bristol.ac.uk](mailto:song.liu@bristol.ac.uk))

GA 18, Fry Building,

Microsoft Teams (search "song liu").

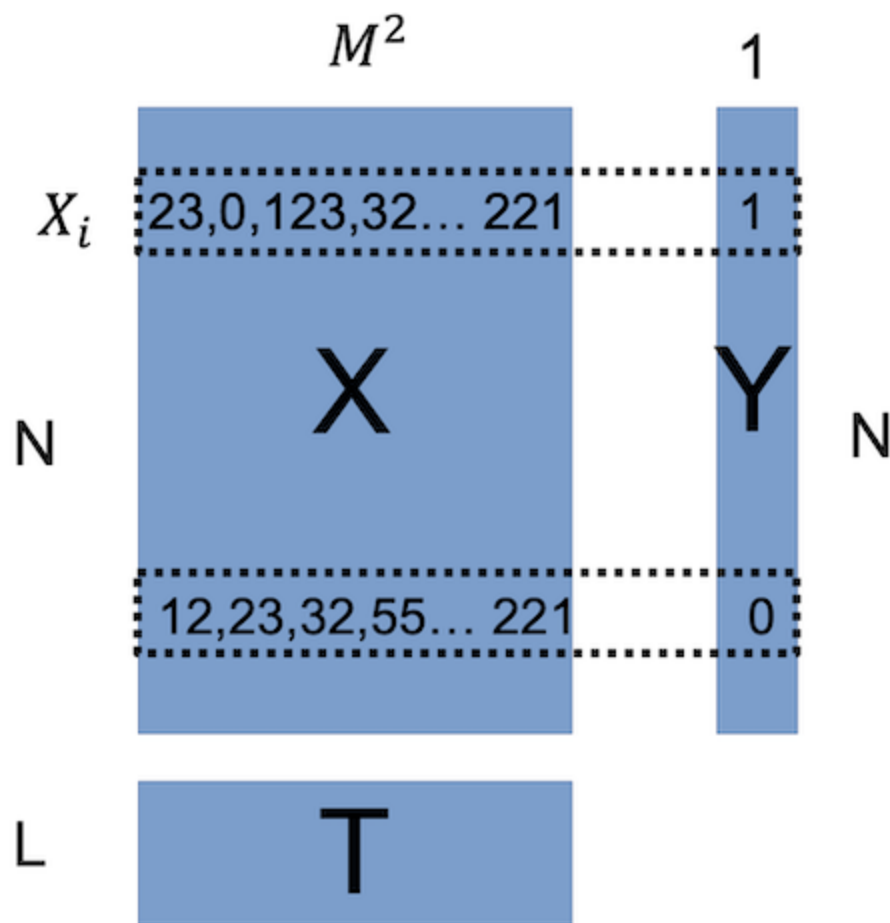
# Final Project: "Recognising" Images

- 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.

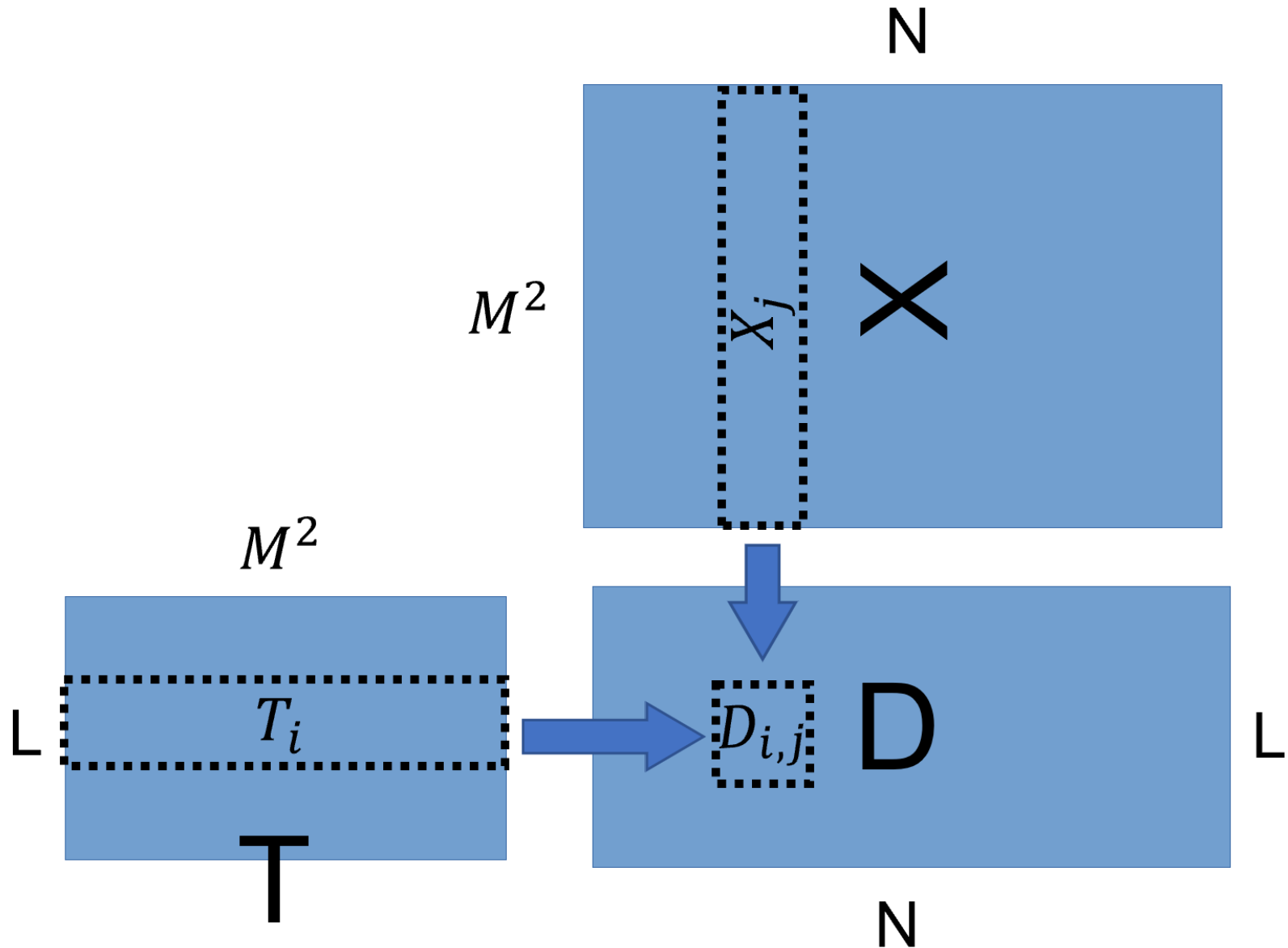
```
struct matrix
{
    int numrow; //number of rows
    int numcol; //number of columns
    int *elements; // pointer pointing to an integer array
    // storing all entries in the matrix in row major order.
};
typedef struct matrix Matrix;
// now "Matrix" is an alias of "struct matrix"
```

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

## 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[])
```

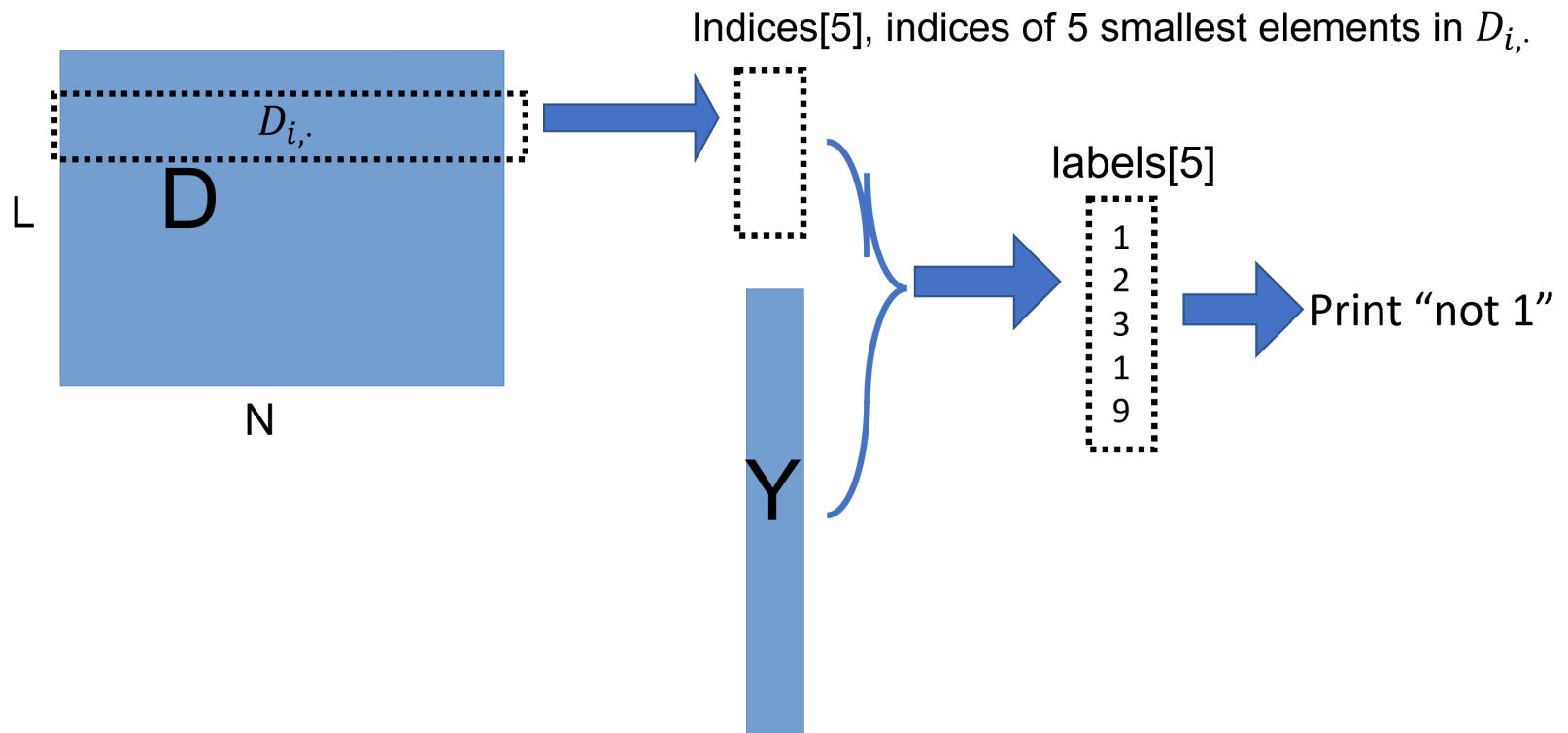
It takes an array `a` with length `len` as input, then fills `indices[]` with the indices of the five smallest elements.

## 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  $\geq 3$ , 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.

