Lecture 1
DSAA Introduction

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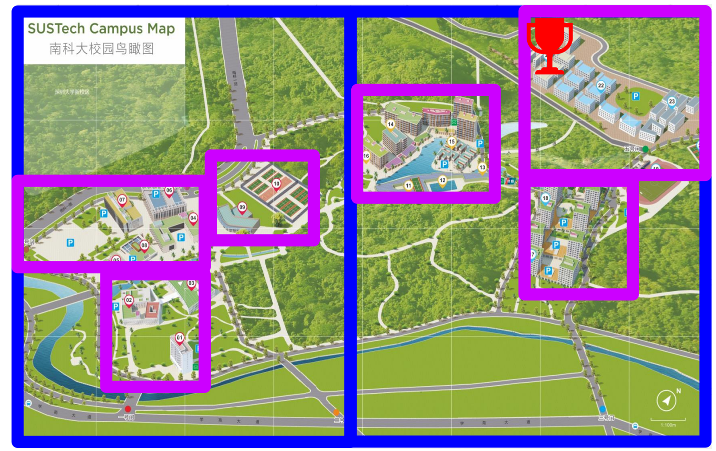
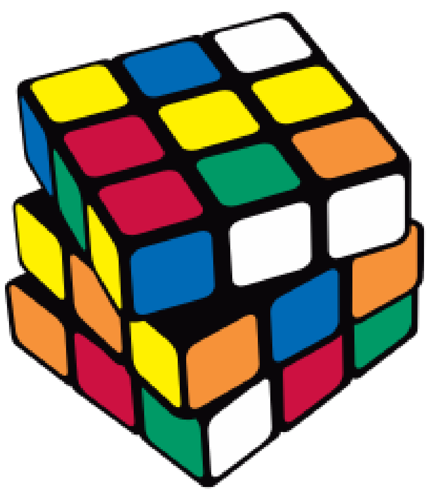
Several pages are based on the notes by Dr. Ken Yiu (PolyU) and Dr. David Sullivan (BU)

Real World Problems

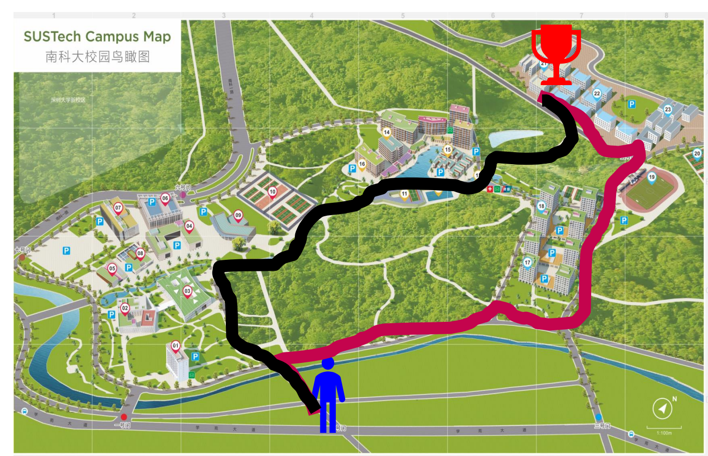
Sort cards



Find a place



Solve a puzzle



Find a shortest path

Problem Solving

- Example: a sorting problem
  - Sort a set of cards
  - Sort the student list according to scores
- How would a human solve a problem?
  - *Uses* brain, hands
- How would a computer solve a problem?
  - *Uses* CPU, memory
  - *basic operations*: compare two integers, move an integer to memory cell X, etc

Algorithms

Algorithms

- *Algorithm*: a well defined sequence of steps for solving a **computational problem**
  - It produces the *correct output*
  - It uses *basic* steps / defined operations
  - It finishes in *finite time*

- Idea of a selection sort method
  - Start with empty hand, all cards on table
  - Pick the smallest card from table
  - Insert the card into the hand

What are the *input*, *output*, and *steps*?

Algorithms

- Example: selection sort algorithm
  - Input: an **array** A of n numbers
  - Output : an **array** A of n numbers in the ascending order
  - Selection-Sort ($A[1..n]$)

1. for integer $i \leftarrow 1$ to $n-1$
2. $\quad k \leftarrow i$
3. $\quad$ for integer $j \leftarrow i+1$ to n
4. $\qquad$ if $A[k] > A[j]$ then
5. $\qquad\quad k \leftarrow j$
6. $\quad$ swap $A[i]$ and $A[k]$

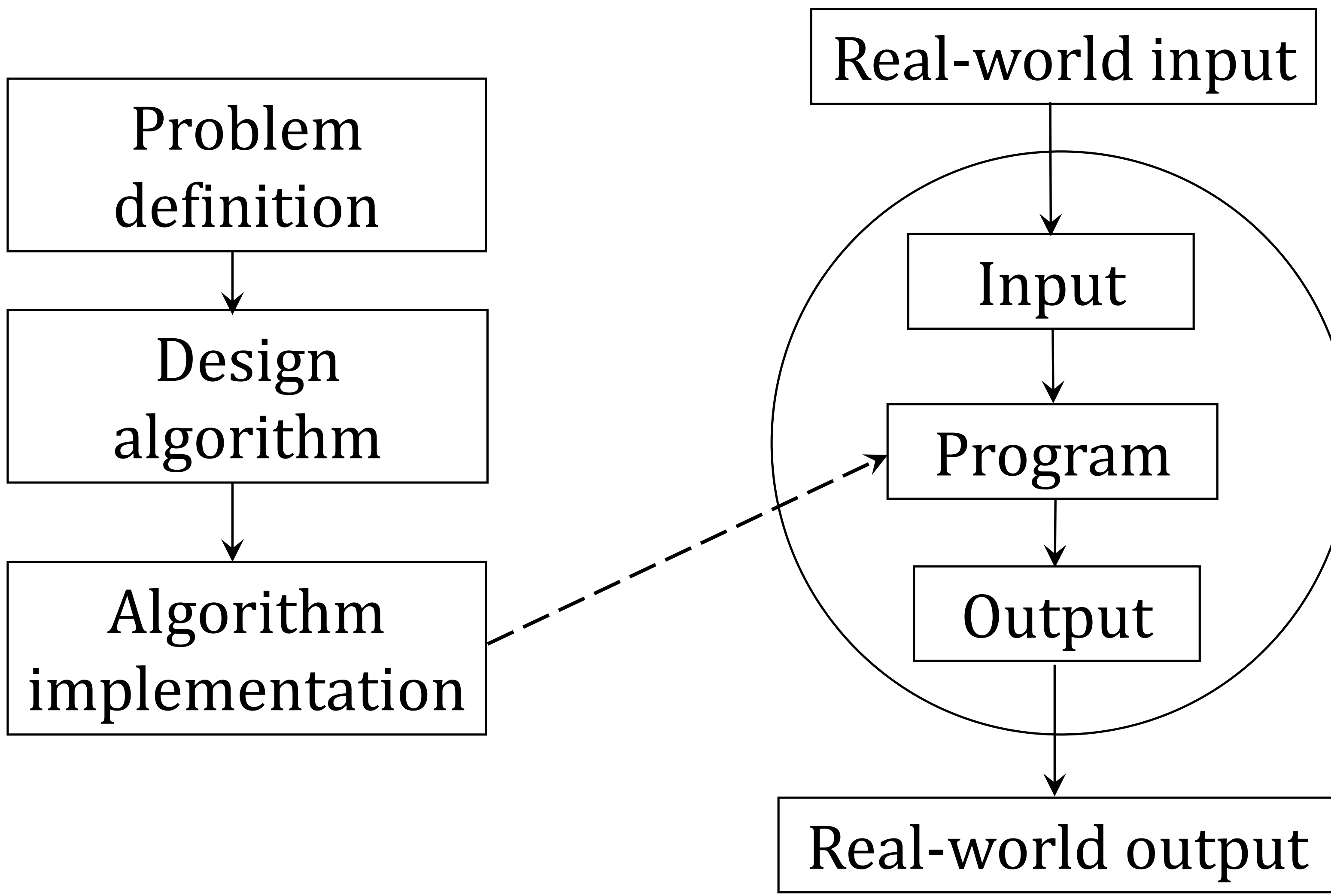
5 | 2 | 4 | 9 | 7

2 | 5 | 4 | 9 | 7

sorted *unsorted*

2 | 4 | 5 | 9 | 7

Algorithms for Problem Solving



Algorithms may use

data structures

Data Structures

- What are human's data structures?
  - Used in libraries, books, clinics, companies, ……

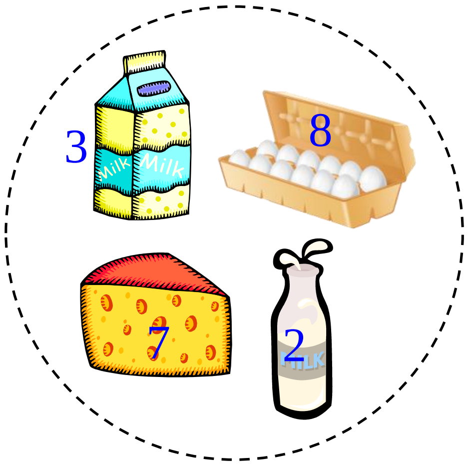
Oriental lampshades, 105-107
Patterns, how to make, 87, 135, 137
Piping, 120
Pleating, 99-104
Pricing your work, 152
Relining lampshades, 118
Rewiring lamps, 80-82
Roses, 126
Ruffles, how to make, 122-123
Scallops, 33, 85
Shampooing lampshades, 151
Shapes of lampshades, 31-41
Silhouettes of lamps, 21-30
Slipcovers for lamps, 108
Smocking, 96, 99
Spiders, different kinds, 31-32
Sunburst pleating, 100-102

- How about computer's data structures?

Data Structures

- Let *S* be a set of items, and *x* be a search key
  - A key is a number, e.g., product id

set



- Useful operations on a set *S*
  - Search(*S*, *x*): search whether *x* appears in *S*
  - Insert(*S*, *x*): insert item *x* into *S*
  - Delete(*S*, *x*): remove item *x* from *S*

search key

- *Data structure*:
  - A way of organizing data objects for efficient usage
  - Building blocks for designing algorithms

Data Structures

You will learn them in this course …

- Why so many data structures?
  - They support different operations, and with different time complexities
- Which data structure is better?
  - Depends on the frequency of operations used in your algorithm
  - E.g., it is fast for the most frequent operation in your algorithm

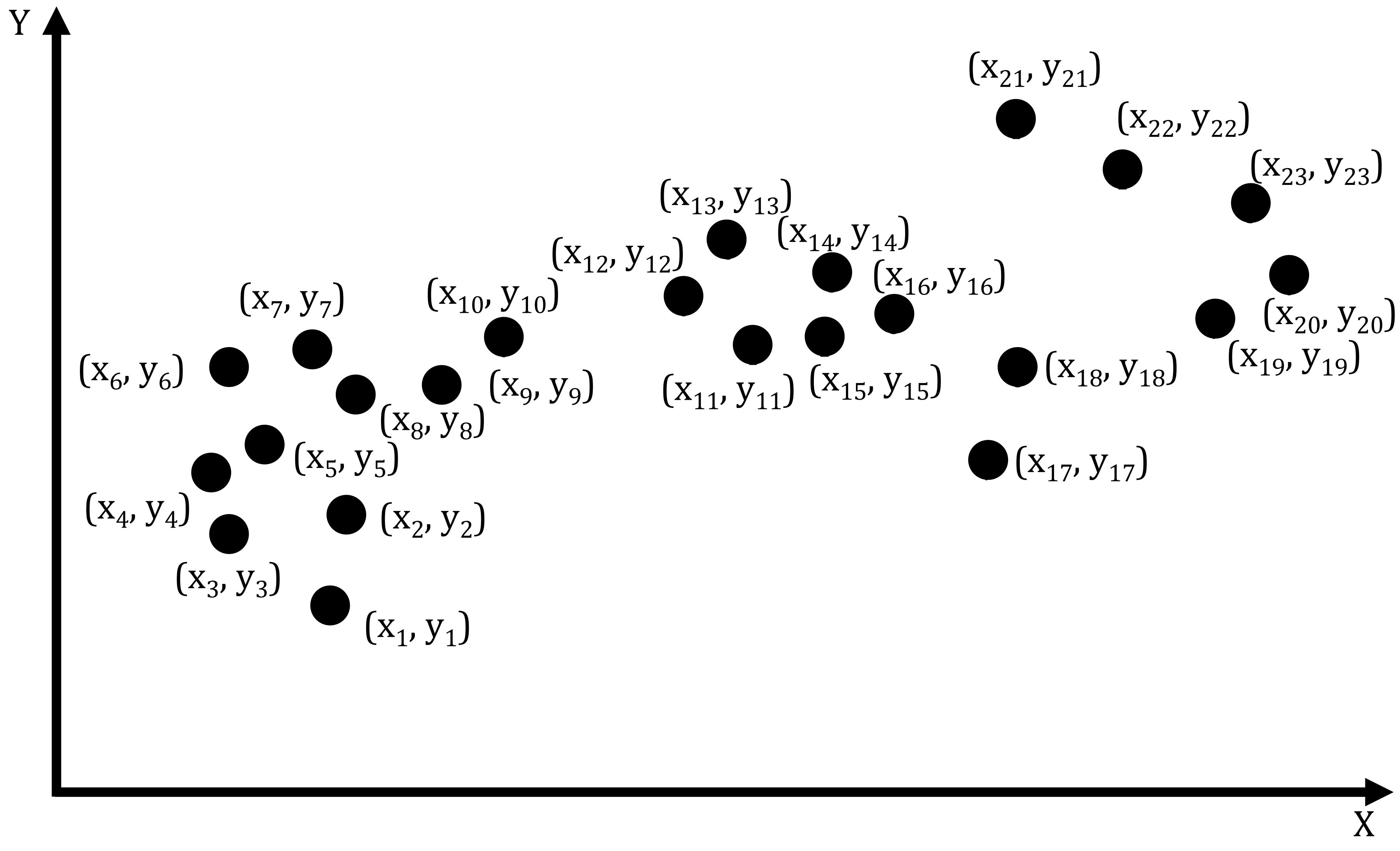
Array
Linked List
Stack
Queue
Hash table
Heap
Tree
……

DSAA demo: find LY102

Find LY102 Classroom 🏆 (x_0, y_0)

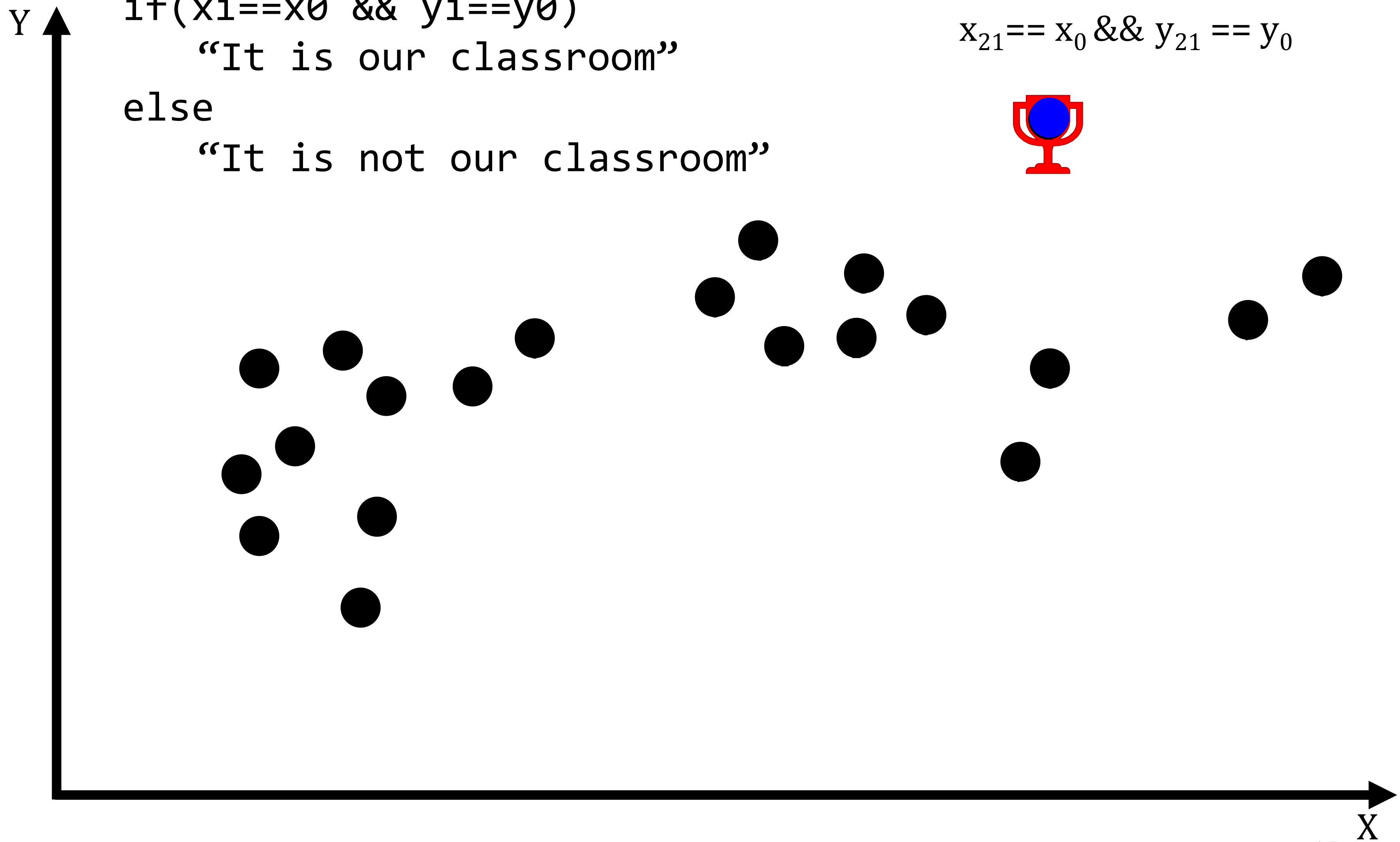
- Any ideas ?

Find LY102 Classroom (x_0, y_0)

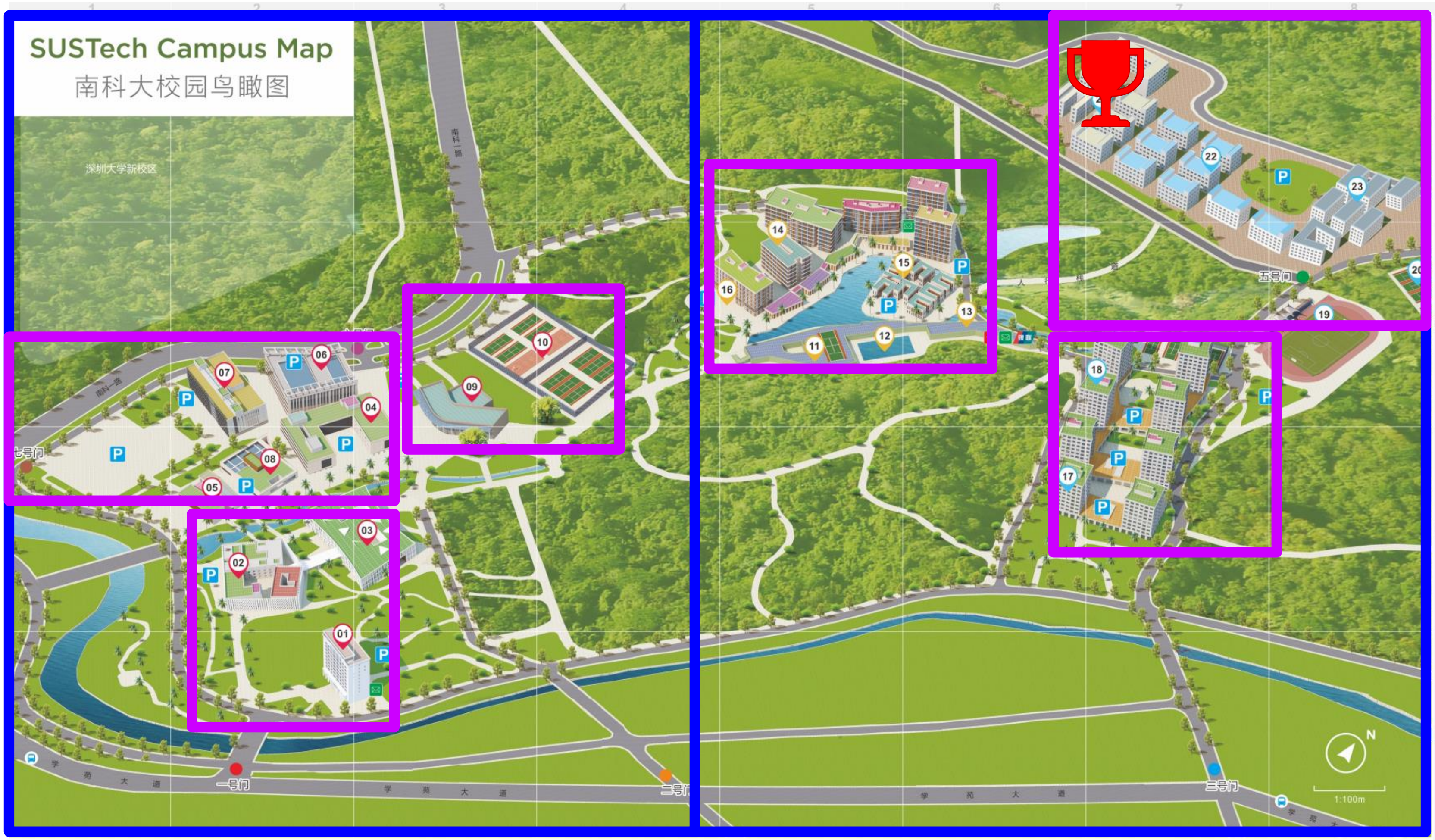


Find LY102 Classroom (x_0, y_0)

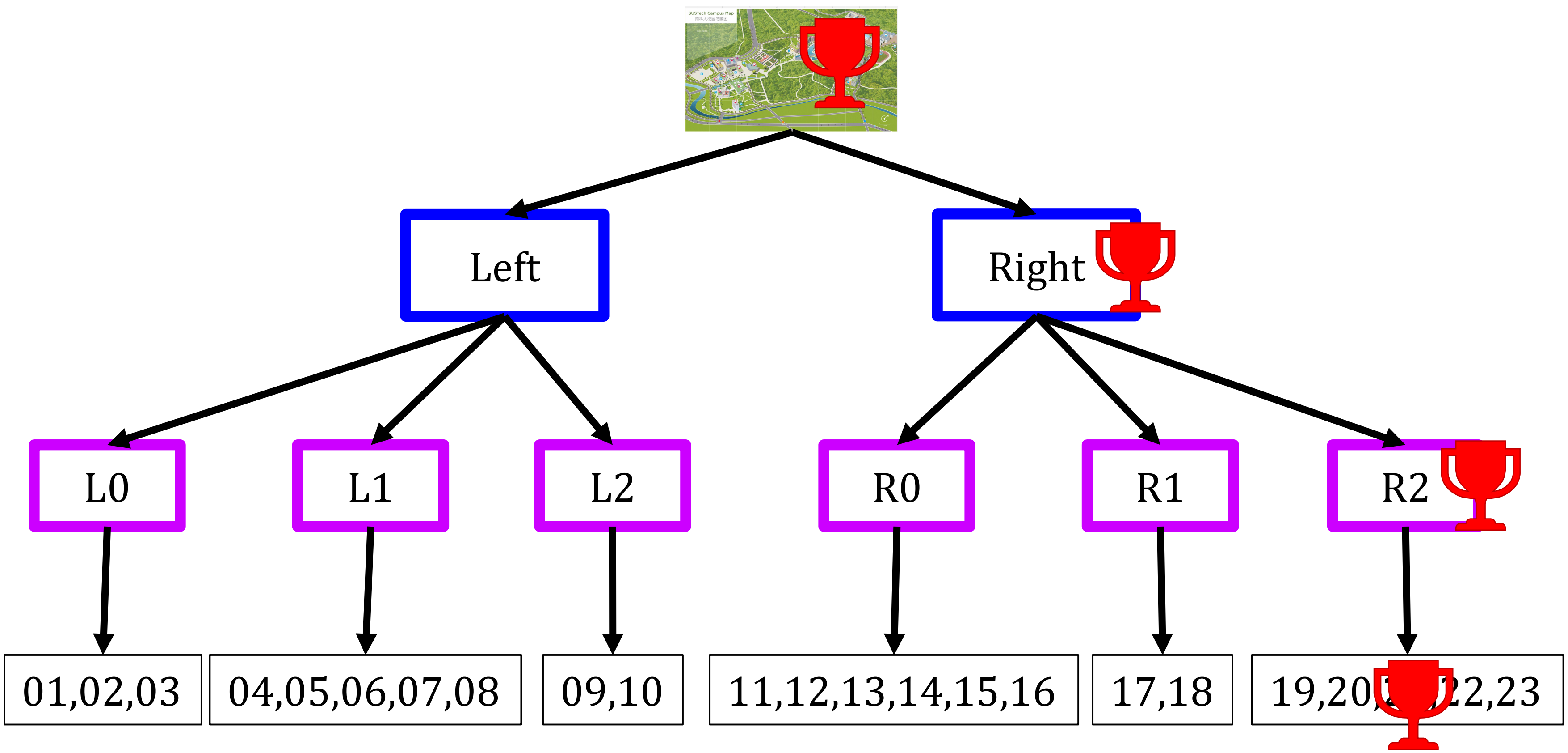
```
if(xi==x0 && yi==y0)
    “It is our classroom”
else
    “It is not our classroom”
```



Find LY102 Classroom



Find LY102 Classroom



Find LY102 Classroom

- Let S be R-tree node, and x be our classroom

- Useful operations on a set S
  - Cover(S, x): verify whether S covers x
  - Children(S): Find the children of S
  - Search(S, x): search whether x appears in S

- *R-tree structure*:
  - A way of organizing data objects for efficient usage
    - Prune a subset of candidates by one checking function
  - Building blocks for designing algorithms

Algorithms Design Techniques

Algorithmic Design Techniques

$1..i{-}1$	i

- *Incremental technique*
  - Build a solution into a larger solution
  - E.g., we have a sorted subarray $A[1..i{-}1]$, then append an item to obtain a sorted subarray $A[1..i]$
- *Recursive technique* (or divide-and-conquer)
  - Reduce the problem into smaller subproblems
  - E.g., find the smallest item in subarray $A[i..n]$, then sort the subarray $A[i{+}1..n]$

i	$i{+}1..n$

Guess the Number Game

- Rules
  - Host: pick a secret integer X from 1 to 20
  - Guest: guess V as the answer
  - → Host: "V is too low" / "V is too high" / "V is correct!"
- Simple strategy: test each integer in ascending order
  - Guess 1 → too low
  - Guess 2 → too low
  - ……
  - Guess 19→ correct!

- Can you suggest a more efficient strategy?

Divide-and-conquer Strategy

- Guess the number game
  - Guess 10 → too low
    - [*Think*] Is X between 1 and 9? NO
    - [*Think*] Is X between 11 and 20? YES

1 - 9	10	11 - 20

  - Guess 15 → too low
    - [*Think*] Is X between 11 and 14? NO
    - [*Think*] Is X between 16 and 20? YES

11 - 14	15	16 - 20

  - Guess 18→ too low
  - Guess 19→ correct!

Recursive Technique

Iteration

- When we encounter a problem that requires repetition, we often use iteration – i.e., some type of loop

- Sample problem: printing the series of integers from n1 to n2, where n1 <= n2.
  - `printSeries(1,8)` should print the following
    1, 2, 3, 4, 5, 6, 7, 8

- Iterative solution:

```
public static void printSeries(int n1, int n2){
    for(int i=n1; i<n2; i++)
          System.out.print(i + ", ");
    System.out.println(n2);
}
```

Recursion

- An alternative approach to problems that require repetition is to solve them using *recursion*

- A recursive method is a method that calls *itself*

- Applying this approach to the `printSeries` problem:

```
public static void printSeries(int n1, int n2){
    if(n1 == n2){
          System.out.println(n2);
    } else {
          System.out.print(n1 + ”, ”);
          printSeries(n1 + 1, n2);
    }
 }
```

Tracing a Recursive Method

- What happens when we execute `printSeries(1,3)`

```
printSeries(1,3):
    System.out.print(1 + ”, ”);    // 1,
    printSeries(2,3):
          System.out.print(2 + ”, ”); // 1, 2,
          printSeries(3,3):
                System.out.println(3); // 1, 2, 3 \n
                return
          return
    return
```

Recursive Problem-Solving

- When we use recursion, we solve a problem by reducing it to a simpler problem of the same kind
- We keep doing this until we reach a problem that is simple enough to be solved directly.
- The simplest problem is known as the ***base case***

```
public static void printSeries(int n1, int n2){
    if(n1 == n2){                   // base case
        System.out.println(n2);
    } else {
        System.out.print(n1 + ", ");
        printSeries(n1 + 1, n2);
    }
}
```

- The base case stops the recursion, because it does not make another call to the method

Recursive Problem-Solving

- If the base case hasn't been reached, we execute the *recursive case*

```
public static void printSeries(int n1, int n2){
    if(n1 == n2){                    // base case
        System.out.println(n2);
    } else {                         // recursive case
        System.out.print(n1 + ", ");
        printSeries(n1 + 1, n2);
    }
}
```

- The recursive case:
  - ***Reduces*** the overall problem to one or more simpler problems of the same kind
  - ***Makes*** recursive calls to solve the simpler problems.

Template of a Recursive Method

```
recursiveMethod(parameters){
    if(stopping condition){
           // handle the base case
    } else {
           // recursive case
           // possibly do something here
           recursiveMethod(Modified parameters);
           // possibly do something here
    }
}
```

- There can be **multiple** base cases and recursive cases

- When we make the recursive call, we typically use parameters that bring us closer to a base case

Printing a File to the Console

- Here is a method that prints a file using **iteration**

```
public static void printFile (Scanner input){
    while(input.hasNextLine()){
        System.out.println(input.nextLine());
    }
}
```

- Here is a method that uses **recursion** to do the same thing:

```
public static void printFileRecursive (Scanner input){
    if(!input.hasNextLine()){ // base case
        return;
    } else { // recursive case
        System.out.println(input.nextLine());
        printFileRecursive(input); // print the rest
    }
}
```

Printing a File in Reverse Order

- What if we want to print the lines of a file in reverse order?
  - It's not easy to do this using iteration. Why?
  - It's easy to do it using recursion!

- How could we modify our pervious method to make it print the lines in reverse order?

```
public static void printFileRecursive (Scanner input){
    if(!input.hasNextLine()){ // base case
            return;
    } else { // recursive case
            String line = input.nextLine();
            printFileRecursive(input); // print the rest
            System.out.println(line);
    }
}
```

Thinking Recursively

- When solving a problem using recursion, ask yourself these questions:
  - How can I break this problem down into one or more smaller subproblems?
    - Make recursive method calls to solve the subproblems
  - What are the base cases?
    - i.e., which subproblems are small enough to solve directly?
  - Do I need to combine the solutions to the subproblems? If so, how should I do so?

Thinking Recursively

```
void 要理解递归()
{
    if (不理解) {
        要理解递归();
    }
}
int main()
{
    要理解递归();
    return 0;
}
```

```
void I_Know_Recursion()
{
        if(I do not know recursion)
        {
                I_Knew_Recursion();
        }
}
int main()
{
        I_Know_Recursion();
        return 0;
}
```

- Is it infinite loop?

Take Home Message

- Algorithms
  - How to sort cards ?
- Data structures
  - How to find our classroom ?
- Divide and conquer strategy
  - How to guess the number game ?
- Iteration
  - How to print a series of numbers
- Recursion
  - How to print a file in reverse order ?
  - Why iteration is not easy to print a file in revers order?

Thank You!