Thomas H. Corman

算法导论

Introduction to Algorithms.

↓

1000多页

makefile

linkcode.

Lecture 1
DSAA Introduction

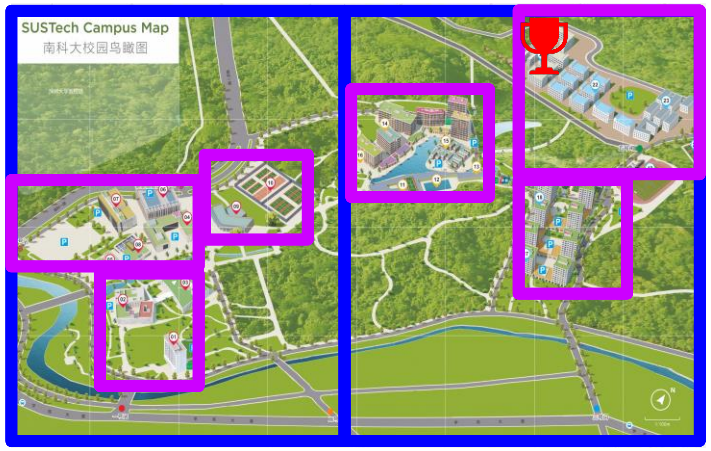
→ 16:00 -17:00 Tuesday

Bo Tang @ 2024, Fall

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

SUSTech Campus Map
南科大校园鸟瞰图

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

算法

Algorithms

- *Algorithm*: a well defined sequence of steps for solving **a computational problem**

  ↳ 可能被计算的问题.

  - It produces the *correct output*
  - It uses *basic steps* / defined operations
  - It finishes in *finite time*

→ 选择排序方法.

- 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

有序

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

Algorithms

n-1轮

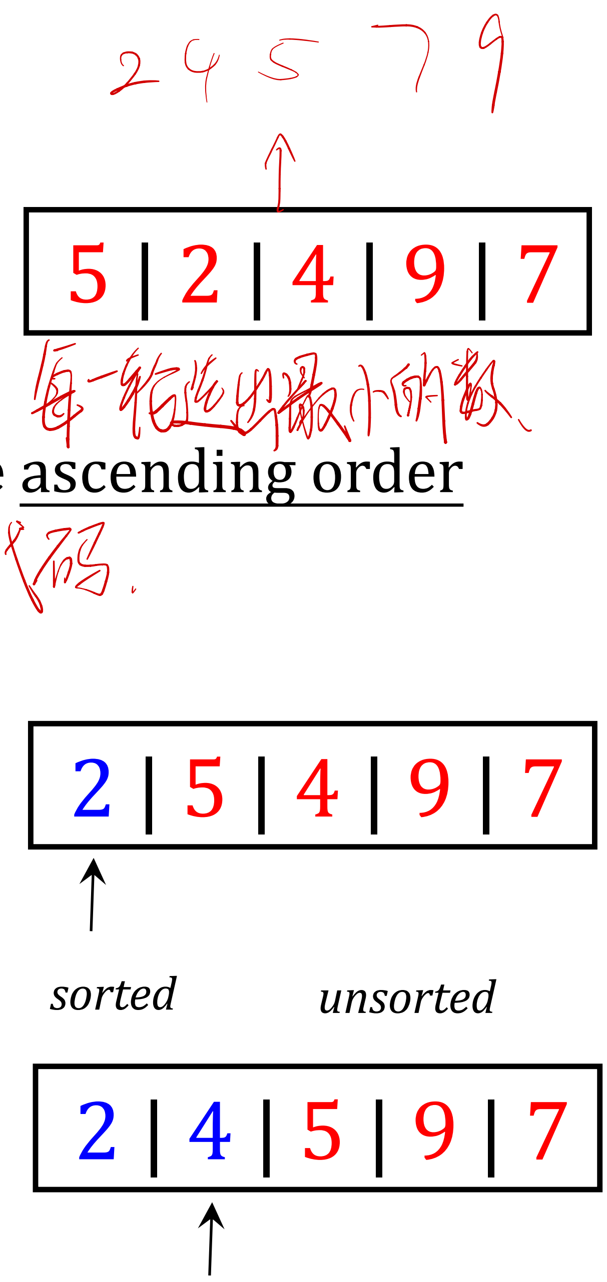
- Example: selection sort algorithm
  - Input: an **array** *A* of *n* numbers
  - Output : an **array** *A* of *n* numbers in the ascending order
  - Selection-Sort (*A*[1..*n*])

伪代码.

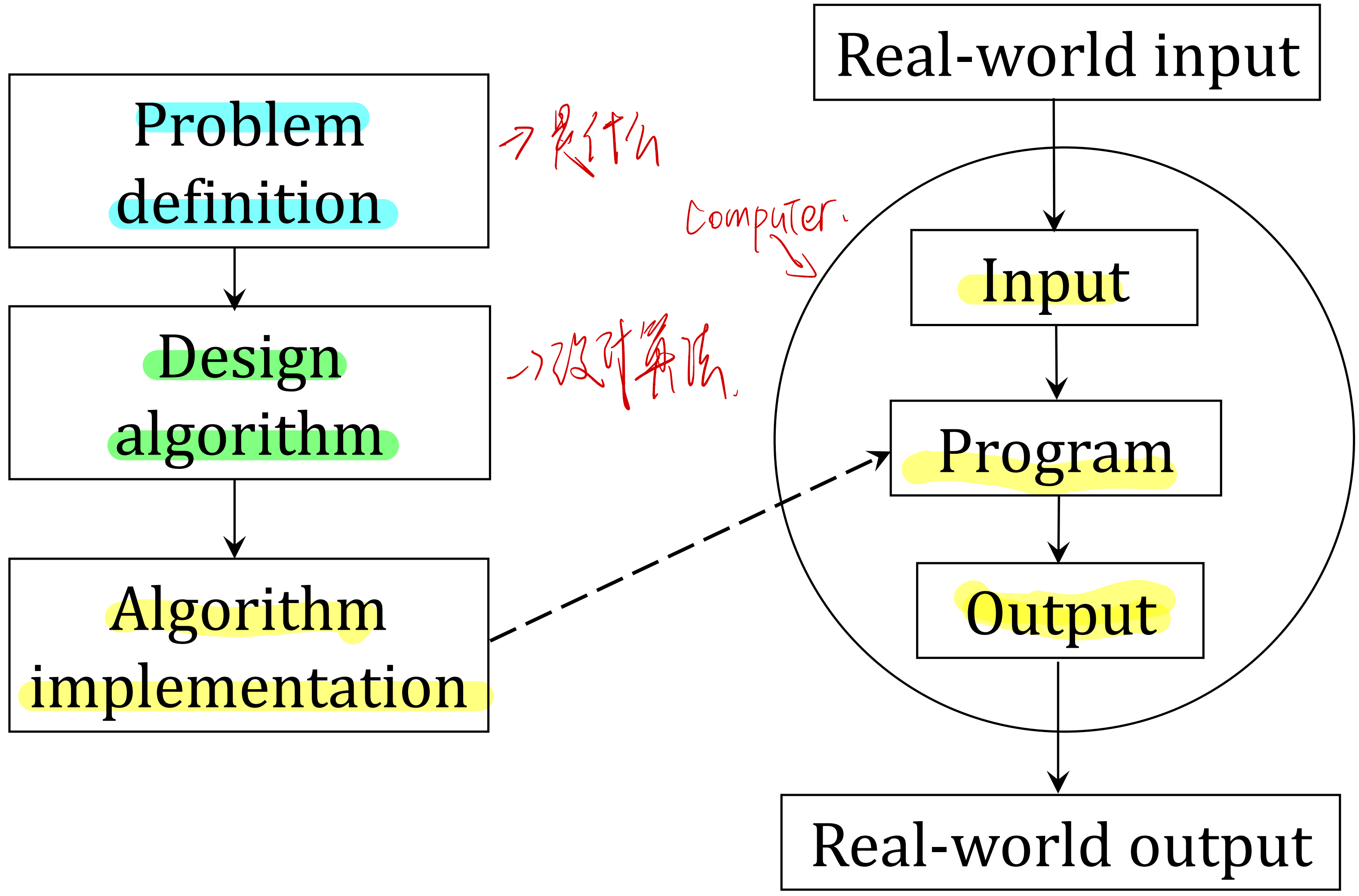
```
1. for integer $i \leftarrow 1$ to $n-1$
2.     $k \leftarrow i$
3.     for integer $j \leftarrow i+1$ to $n$
4.         if  $A[k] > A[j]$  then
5.             $k \leftarrow j$
6.     swap $A[i]$ and $A[k]$
```

在剩下的数中找最小的数

换位.



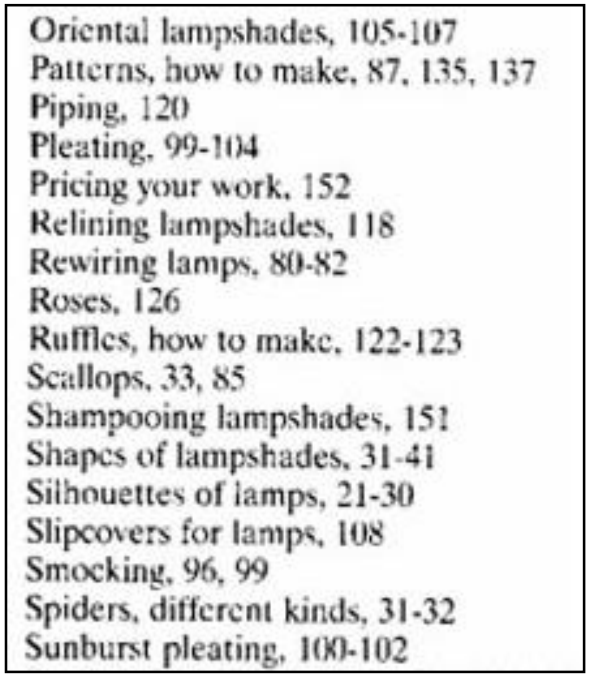
Algorithms for Problem Solving



Algorithms may use
data structures

Data Structures

- What are human's data structures? 方便寻找数据
  - Used in libraries, books, clinics, companies, ……



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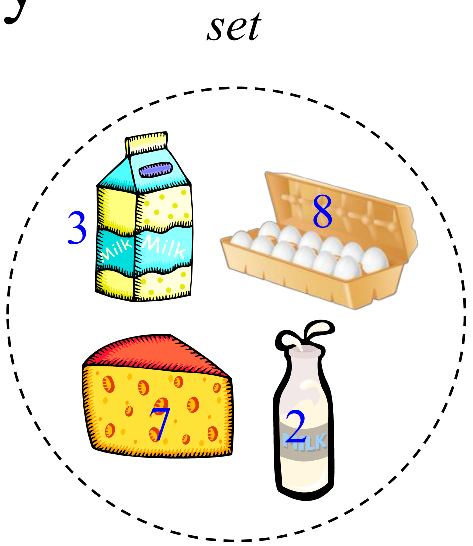
- How about computer's data structures?

Data Structures

- Let *S* be a set of items, and *x* be a search key
  - A key is a number, e.g., product id
- 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*
- *Data structure*:
  - A way of organizing data objects for efficient usage
  - Building blocks for designing algorithms



DS ~ Data Structures

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

You will learn them in this course ...

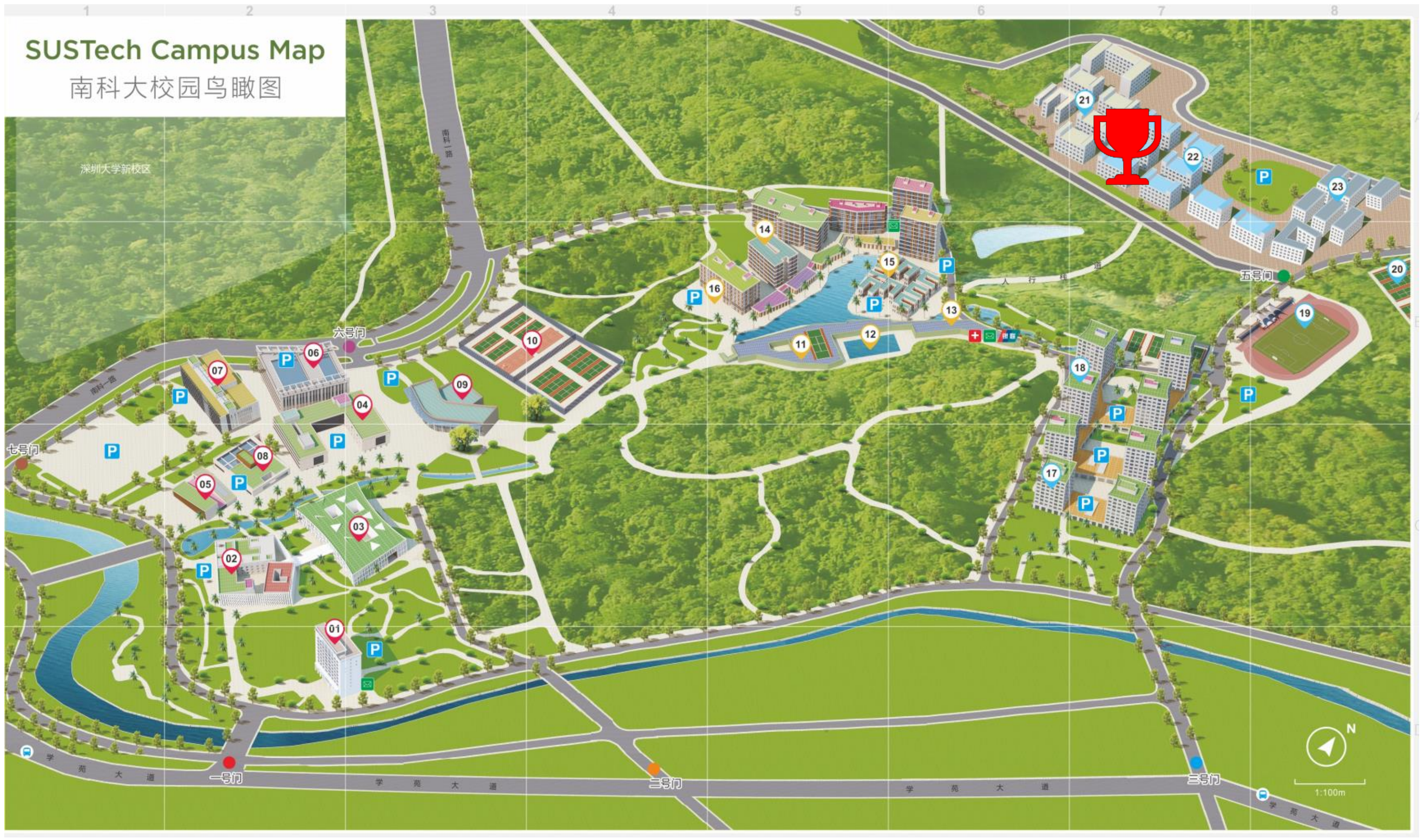
各种数据类型

Array
Linked List
Stack
Queue
Hash table
Heap
Tree
……

DSAA demo: find LY102

Find LY102

(x_0, y_0)



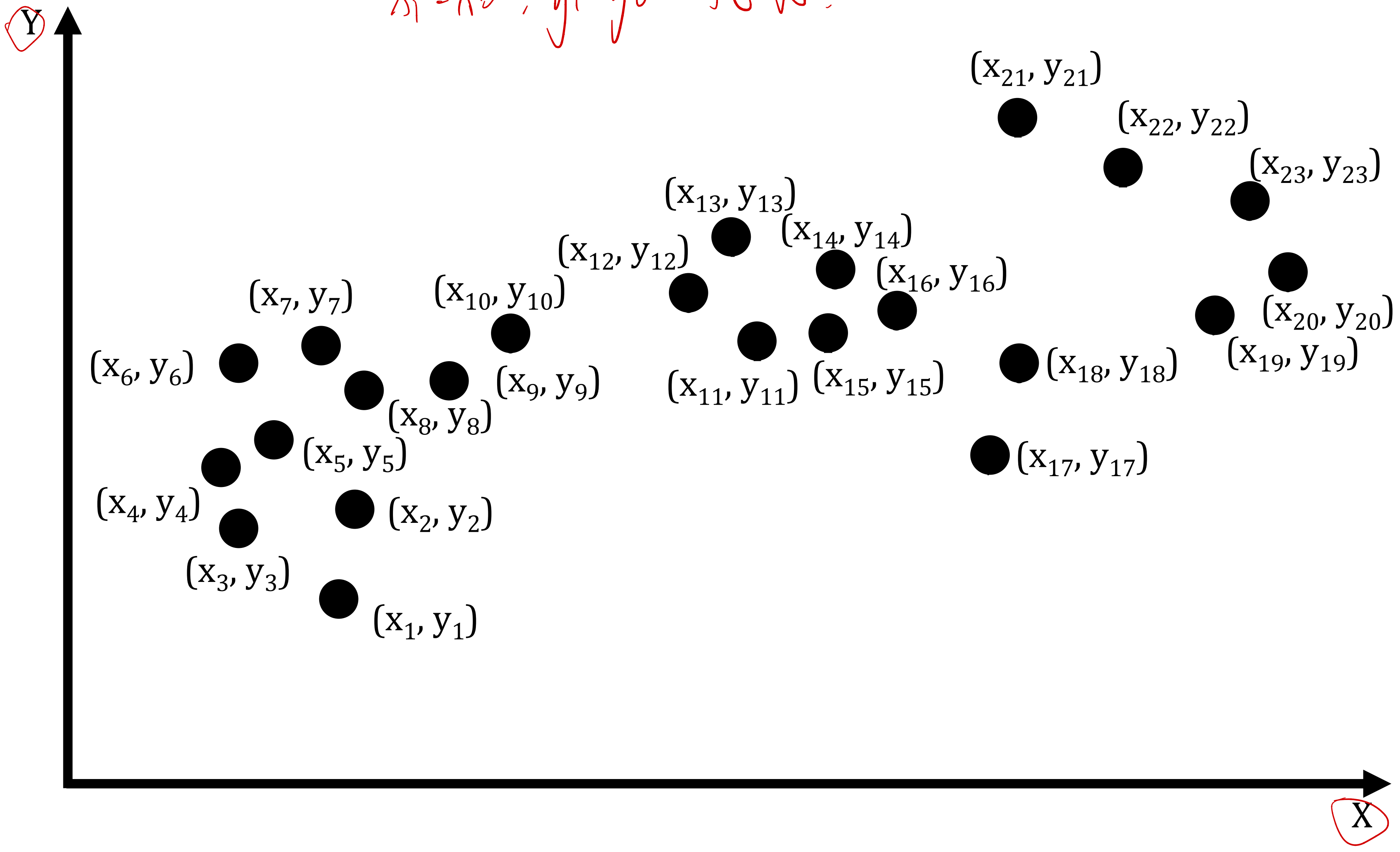
- Any ideas ?

找坐标.

Find LY102

$x_i = x_0, y_i = y_0 \rightarrow$ 找到.

🏆 (x_0, y_0)

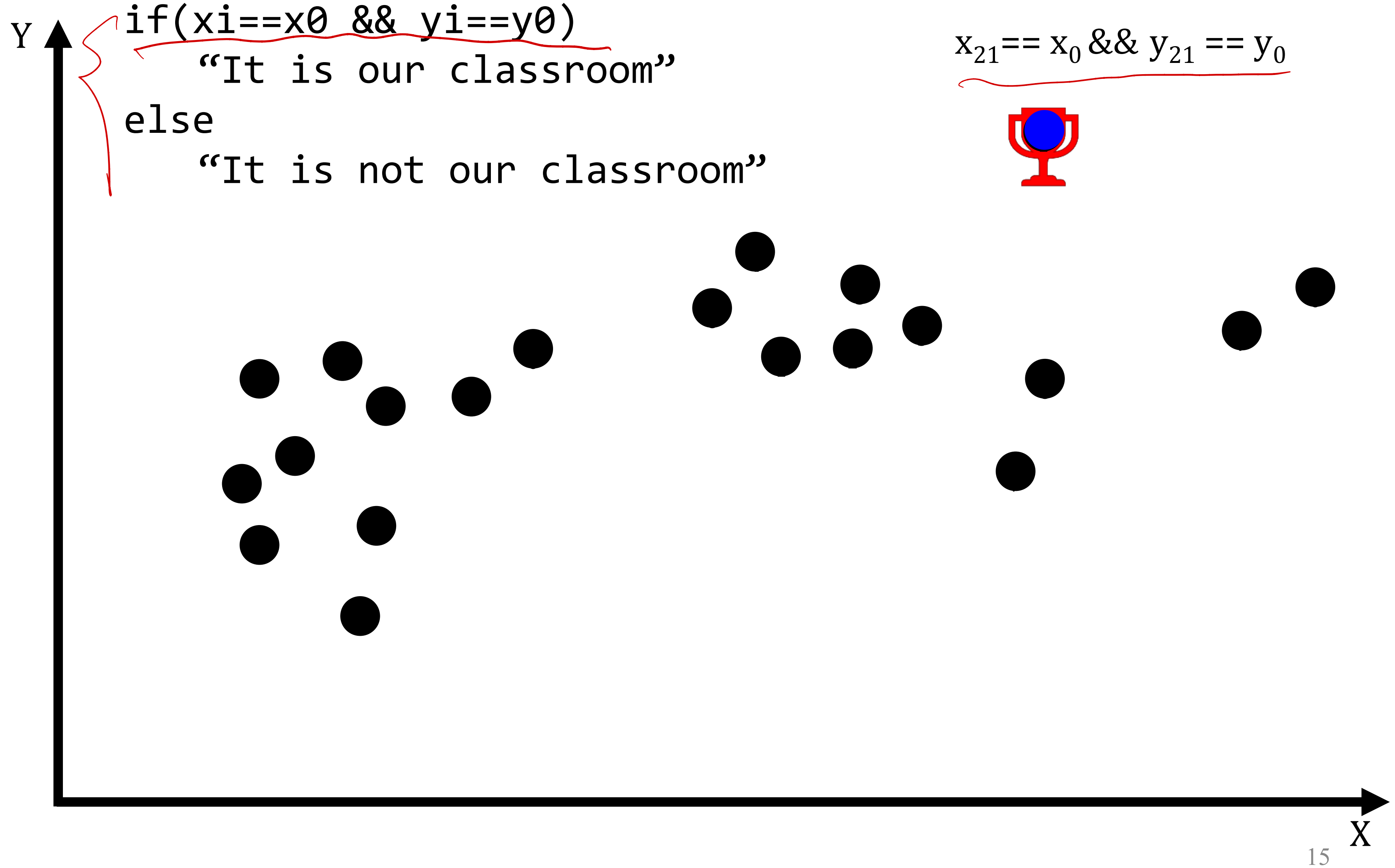


Find LY102

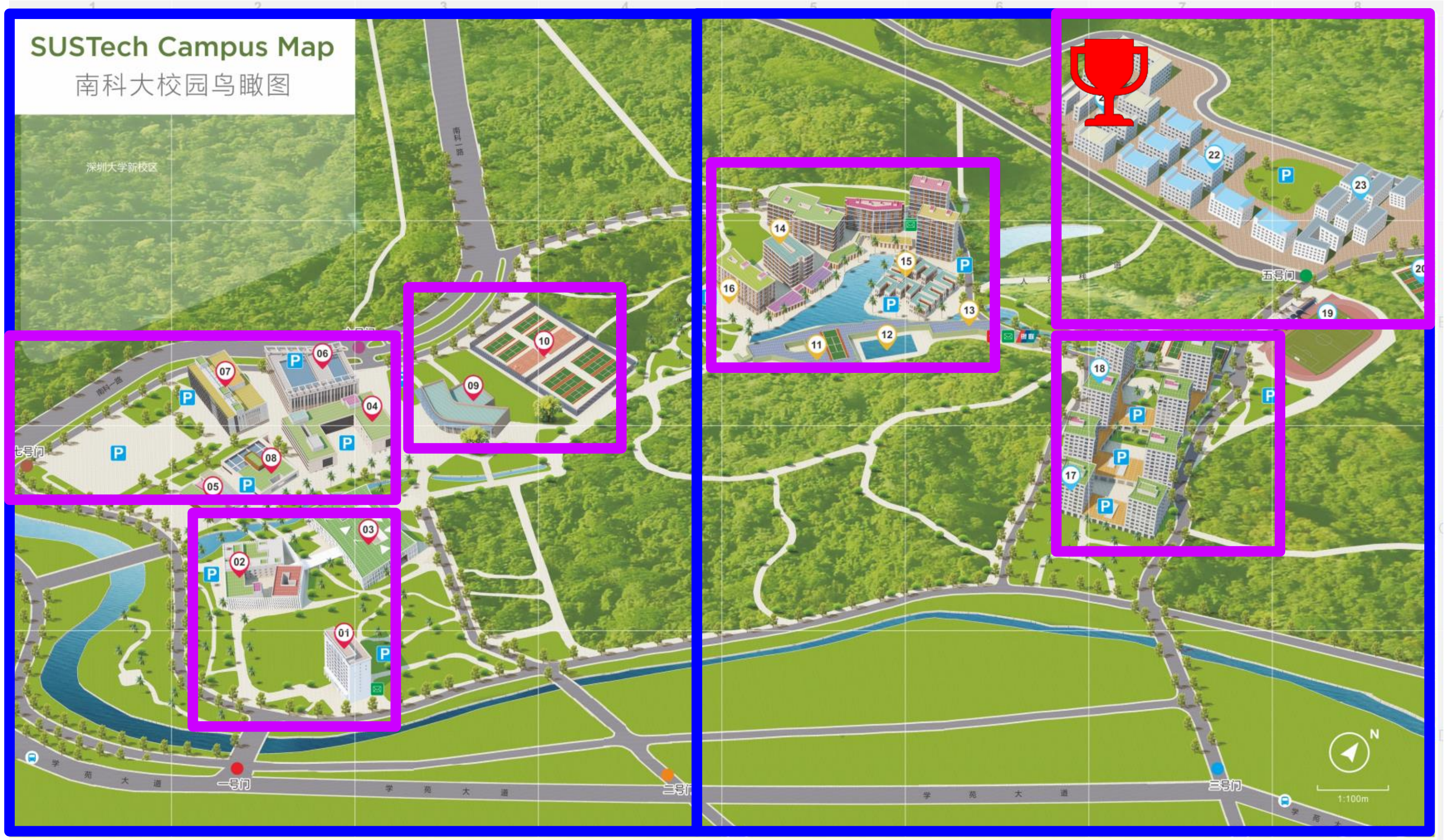
(x_0, y_0)

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

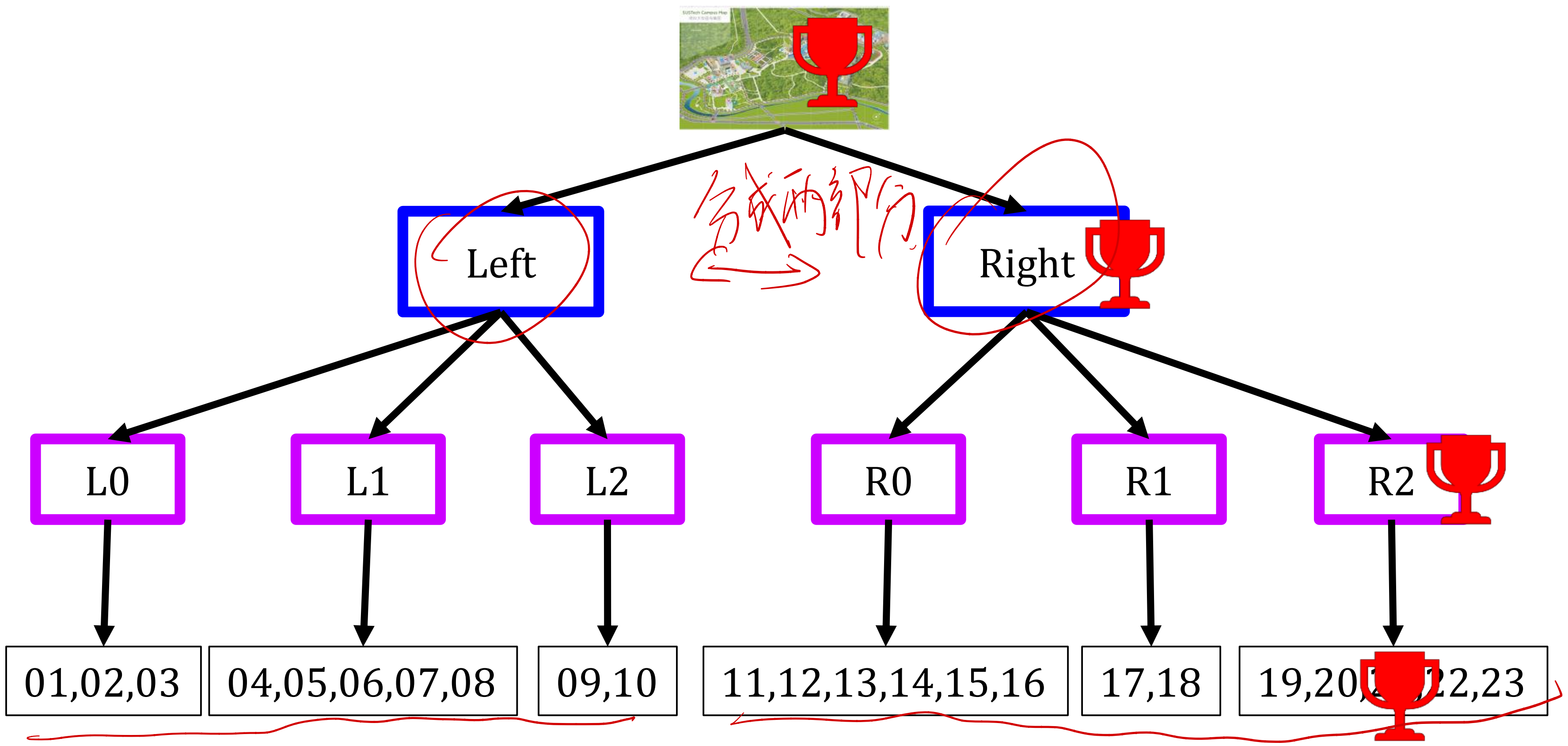
$x_{21} == x_0 \ \&\& \ y_{21} == y_0$



Find LY102


SUSTech Campus Map
南科大校园鸟瞰图
深圳大学新校区
七号门
一号门
二号门
三号门
五号门
学苑大道
1:100m
N

Find LY102



Left
分成两部分
Right
L0
L1
L2
R0
R1
R2
01,02,03
04,05,06,07,08
09,10
11,12,13,14,15,16
17,18
19,20
22,23

Find LY102 Classroom

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

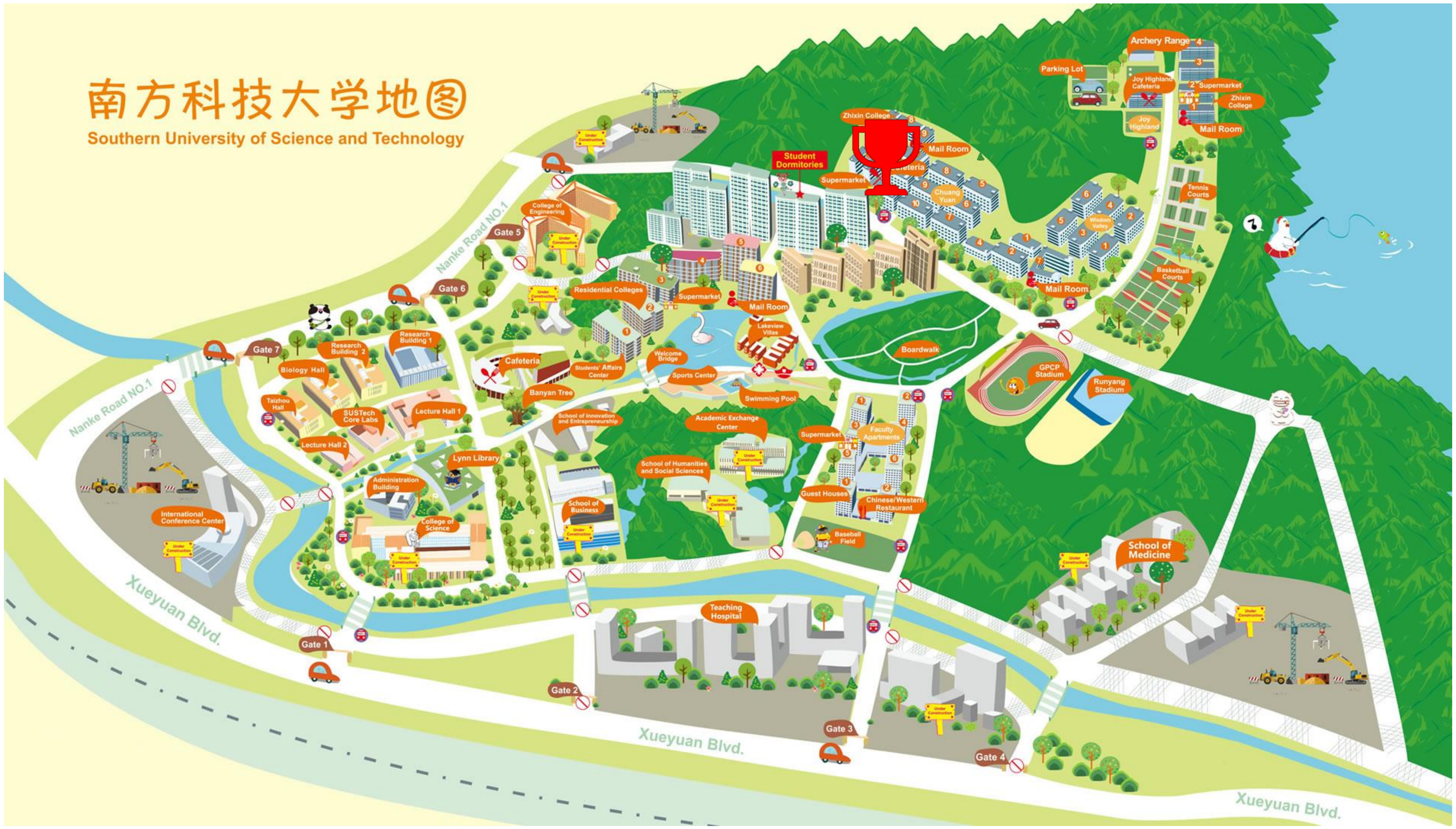
  ↳ 一种数据结构 (多维空间索引)

- 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

Find LY102

(x_0, y_0)



- Any ideas ?

Algorithms Design Techniques

Algorithmic Design Techniques

- *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 $A[i+1..n]$

Guess the Number Game

二分法.

- 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

二分法

- 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

更快

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

递归

```
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!

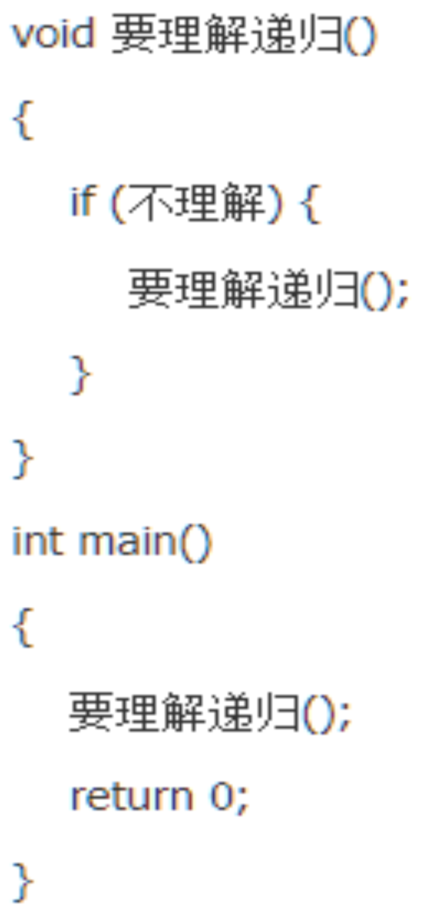
- How could we modify our pervious method to make it print the lines in reverse order?

```
 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_Know_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!