Functions and Data Structures

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Where innovation starts

Overview of this lecture

- Functions
- Data structures: Arrays
- (Working with data structures)

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Functions

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Functions: what?

- DRY principle: Don't Repeat Yourself! → Reusable blocks of code
- Add structure and flexibility to your programs
- Make your programs better understandable
- Has parameters and can return a value

```
void setup(){
    size(400,400);
    background(255);
    drawRectangle(150, 150, 100, 100);
}
void drawRectangle(float x, float y, float w,
float h){
    rect(x, y, w, h);
}
```

Function call

Function definition

Functions: general structure

return_type function_name(optional parameters){

code to execute when function is called

optional return

}

```
int add(int a, int b) {
     return a + b;
}
```

- A function starts with a return type (use “void” if no return is needed)
- An identifier (the name of the function)
- Open and closed parentheses: optional parameters
- Open and closed curly braces

Functions: Another example

```
void setup(){
    size(400, 400);
    background(255);
    for(int i=0; i<100; i++){
        drawRectangle(random(width), random
        (heigth), random(200), random(200));
    }
}
```

- How many function *definitions* and how many function *calls* do you see?
- What will happen?

Functions: strengths

- Use of different parameters
- Efficient by avoiding redundant code
- Less errors by writing the code only once (in the function)
- Freed from writing linear code
- Once a function is defined, you can call it whenever you need it

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Functions: parameters & arguments

- Parameters in function *definition* should match arguments passed in function *call*

```
void myFunction(int x, int y){…}
void myFunction(int x, int y, int z){…}
void myFunction(float x, float y, float z){…}

myFunction(2, 5);
myFunction(2, 5, 7);
myFunction(2.0, 3.4, 2.33);
```

- What happens with the call `myFunction(2, 2.3);` ?
- What happens with the call `myFunction(2, 2.0);` ?

Functions: return

- Each function that has a return type other than *void* must have a return statement (often as the last line)

```
int sum;
int computeSum(int x1, int x2, int x3){
  // you could do all sorts of stuff before the return
  return x1 + x2 + x3;
}
sum = computeSum(4, 5, 6);
```

Functions: do not use hard coded numbers

- Does not facilitate evolution and flexibility of code

Bad example:

```
size(200, 200);
background(255);
strokeweight(5);
stroke(20);
fill(100);
rect(50, 50, 100, 100);
```

Functions: do not use hard coded numbers, ctd.

- Use parameterized function

```
void setup(){
    size(200,200);
    background(255);
    createRect(50, 50, 100, 100, 20, 5, 100);
}
// parameterized function
void createRect(int xpos, int ypos, int width, int
height, int strokeColor, int strokeWeight, int
fillColor) {
    stroke(strokeColor);
    …
    rect(xpos, ypos, width, height);
}
```

Data structures: Arrays

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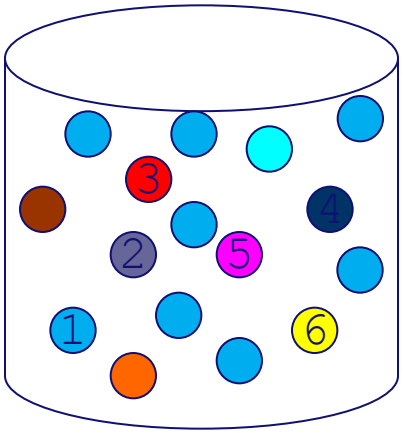
Arrays Intro

- Suppose you have a bag of 100 balls
- For each of them you want to save their color value



String ball1 = “blue”;

String ball2 = “purple”;

…

String ball100 = “orange”;

Arrays: the Idea

- One container, data structure to store all of them

- Compare to a desk with multiple drawers

Arrays: the Idea

- Single entity with one name
- Can hold multiple values
- Accessible through indexing
- Important data structure in coding
- Efficient storage in memory, fast access

  (if you know the right index)

Arrays: Syntax

- Declare with a datatype

```
String[] listofballs;
```

- Same declaration as a variable that holds a single string, with [ ] added
- More examples

```
int[] xpos;
float[] xspeed;
boolean[] ledsOn;
```

Arrays : types and size

- `float, int` are lowercase: primitive datatype
- `String`, initial cap: name of predefined class
- Can be of any size

  (limited to size of int datatype: 2,147,483,647)
- Can hold any legal type
- But: Once declared, type cannot be changed

What is the difference between:

`String[] listofballs;` and

`String listofballs[];` ?

Arrays : types and size ctd.

- Example:

```
float[] xspeed;
```

- Now it can only hold values of type float
- Initialization:

```
xspeed  = new float[100];
```

- `new` reserves memory
- *xspeed* now has 100 `float` places in memory

Arrays : types and size ctd.

- Declaration and initialization can be merged into one statement:

```
float[] xspeed = new float[100];
```

- Another example:

```
Object[] obs = new Object[0];
```

Arrays: alternative initialization

```
int[] speeds = {2, 4, 445, -120, 3, 54};

String[] names = {“Jun”, ”Loe”, ”Peter”};
```

Arrays: indexing

- Start with “0”
- `int firstelement = speeds[0];`

- Length is the actual number of items in the array
- `int length = speeds.length;`

- Compile error when you go out of range (try it!)

- How can I store the value 6.7 in place 4?
- How can I get the last value of an array?
- Can you write this as a function?

Looping over an array

```
String[] firstNames = {“Rene”, ”Karl”, ”Sjriek”,
”Peter”};

for(int i=0;i < firstNames.length; i++){
    println(firstNames[i]);
    println();
}
```

What is the result?

Can you write this as a function?

Working with data structures

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Content

- General principles
- Searching
- Sorting
- Optimising (more algorithms and data structures)

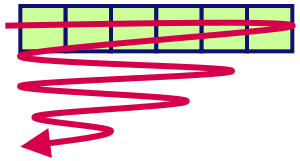
General principles

- Data structures
  - built from variables, arrays, or objects refering to each other
- Algorithms
  - built from if, if-else, for, while, functions calling each other
- To be designed together
  - like the railway topology and the train schedule
  - you cannot design an efficient train schedule unless you know the railway topology

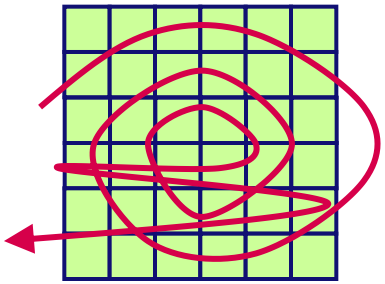
General principles (continued)

- Searching
  - one-dimensional problems
  - with single-loop solutions

- Sorting
  - one-dimensional problems
  - with nested-loop solutions
  - useful to prepare for easy searching



- Optimising
  - two-dimensional problems
  - with complex nested-loop solutions
  - good example: shortest path problems
  - useful in route planners and internet packet routing



General principles (continued)

- Issues
  - correctness
  - efficiency
- Correctness
  - respecting array bounds
  - not using null pointers
  - initialising all variables
  - careful reasoning
- Efficiency
  - data structures for memoization
  - $\mathcal{O}(n)$ is better than $\mathcal{O}(n^2)$ and $\mathcal{O}(n^3)$
  - sometimes one has to accept $\mathcal{O}(e^n)$
  - use existing classics

Searching

- Basic idea
  - data in one array
  - scan the entire array with one for-loop

- Basic code

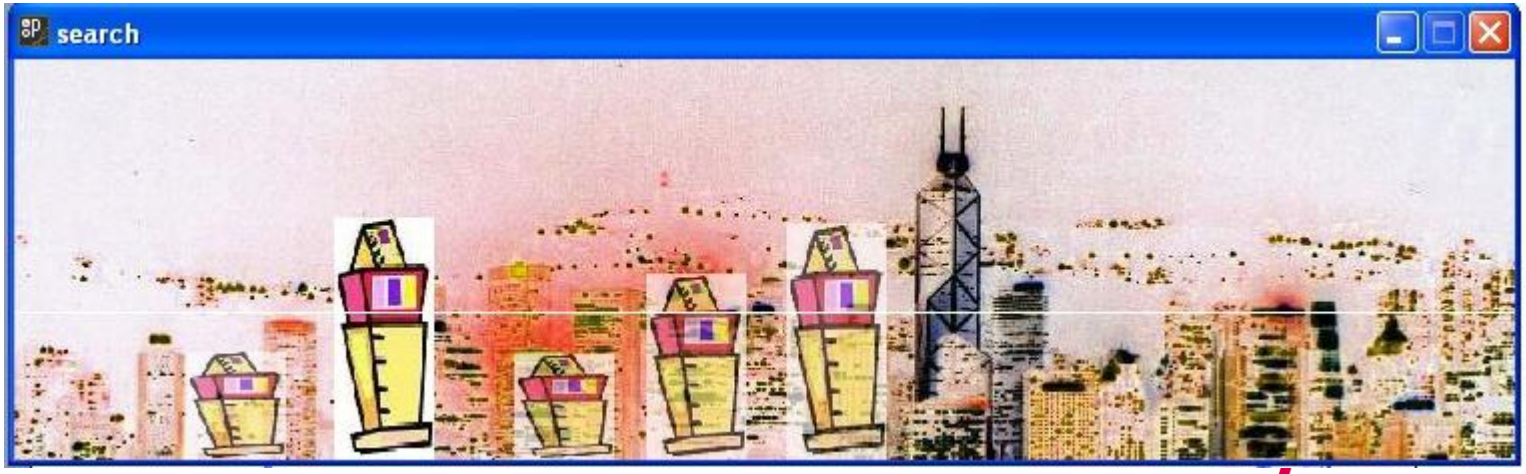
```
int[] a=new int[N];
// a is filled here
for (int i=0; i < N; i++) {
    if  (a[i] == x) {
        // aha, x found!
    }
}
```

Searching

- Tricks of the trade
  - for an array of N elements
  - the indexes run from 0 to N-1
  - use a local loop counter named i, j or k
  - use a boolean variable “found” to stop once your x is found
  - use the pseudo value infinity to begin a min or max loop

Searching

- Demo application
  - edit an array of towers
  - random height levels
  - calculate average
  - find the tallest



Searching

- Interface of the demo

The construction truck is at horizontal position x

```
void keyPressed() {
  if(keyCode == LEFT)  { x=x-2; }
  if(keyCode == RIGHT) { x=x+2; }
  if(key == ' ') { // add tower
      if (towers<maxtowers){
        loc[towers]=x;
        lvl[towers]=floor(random(0,200));
        towers++;
      }
  }
  if(keyCode == ENTER) { done=true;}
}
```

For each tower index there is a location loc and a height level lvl

Searching

- Action of the demo

```
// in draw
if (done) {
        int i=tallest();
        tint(255,255);
        image(tower,loc[i],200-lvl[i],50,lvl[i]);
        int a=average();
        stroke(255);
        line(0, 200-a, 750, 200-a);
}
```

Finding a maximum

Calculating an average

Searching

- Finding a maximum

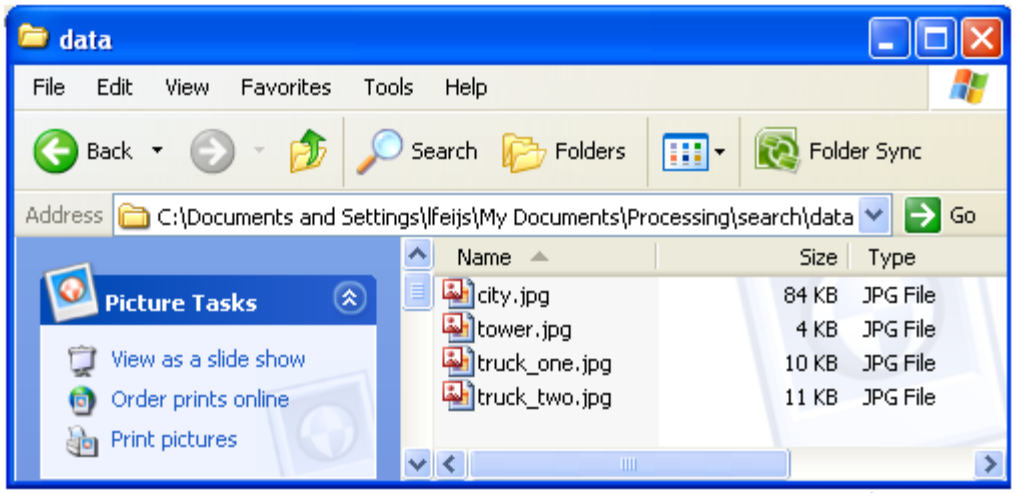
```
int tallest() {
    int m=-1; // max level found so far
    int i=-1; // index where it's found
    for (int j=0; j<towers; j++)
        if (lvl[j] > m) {
            m = lvl[j];
            i = j;
        }
    return i;
}
```

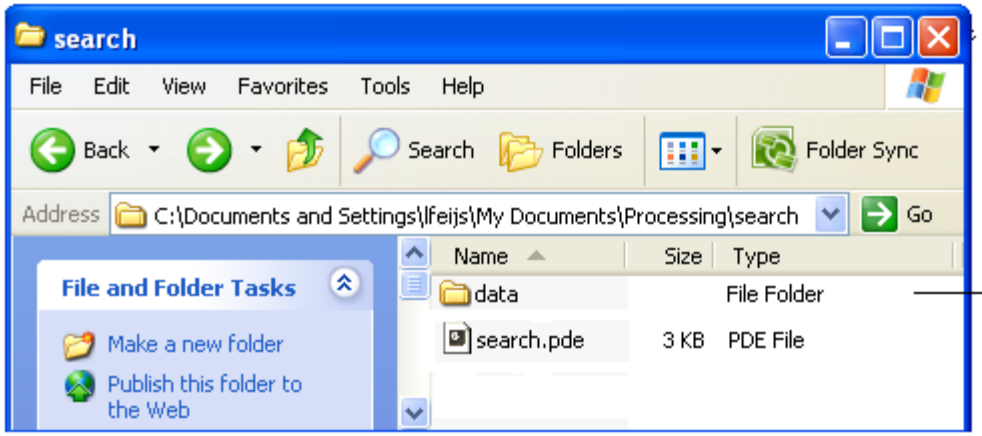
Searching

- Calculating an average

```
int average() {
     int s=0; // sum calculated so far
     for (int j=0; j<towers; j++) {
            s = s+lvl[j];
     }
     if (towers > 0) {
            return s / towers;
     }
     else {
            return 0;
     }
}
```

Searching (more about the demo)





Exercises on searching

- Do it yourself
  - Find the lowest tower!
- Food for thought
  - Can you find the median?

Sorting

- Demo application
  - edit an array of towers
  - three tower types
  - towers as objects
  - sort by level

Sorting

edit

sort

Sorting

- Selection sort
  - noted for its simplicity
  - see e.g. (Dutch) wikipedia, selection sort
  - more: heapsort, insertion sort, bubble sort, quicksort, Shellsort, …

```
// invoer = array met integers
for (int i = 0; i < array.length; i++) {

        // zoek kleinste in de rest van de array
        int minIndex = i;
        for (int j = i; j < array.length; j++) {
                if (array[j] < array[minIndex]) {
                        minIndex = j;
                }
        }

        // verwissel waarden
        int temp = array[i];
        array[i] = array[minIndex];
        array[minIndex] = temp;
}
```

Sorting

```
void selectionSort(){
     for (int i = 0; i < towers; i++) {
      // when here: i smallest values are sorted in 0..i-1
      int mi = i;
      for (int j = i; j < towers; j++) {
          // when here: mi is index of smallest in i..j-1
          if (twr[j].lvl < twr[mi].lvl)
              mi = j;
      }
      // swap towers at indexes i and mi
      Tower tmp = twr[i]; twr[i] = twr[mi]; twr[mi] = tmp;
   }
}
```

Sorting (oo)

- Object orientation
  - instead of 3 arrays of single tower-attributes

```
int[] loc = new int[maxtowers]; // location, i.e. x value
int[] lvl = new int[maxtowers]; // level, i.e. height
int[] typ = new int[maxtowers]; // type, either 0,1, or
```

  - define one array of tower objects with 3 attributes each

```
class Tower {
  int loc; // location, i.e. x value
  int lvl; // level, i.e. height
  int typ; // type, either 0,1, or 2
  // etc.
}

Tower[] twr = new Tower[maxtowers];
```

Exercises on sorting

- Study and run the sorting demo
- Do it yourself
  - bubble sort
  - e.g. read wikipedia: bubble sort sort
- Food for thought
  - now can you find the median?