Data Structures and Algorithms

XMUT-COMP 103 - 2025 T1

Algorithms: recursion

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Problem Solving / Algorithm Design

A Key principle of problem solving:

- Break problems up into smaller chunks to solve independently

EG: Iteration:

- To do something to lots of items:
  - work out how to do it to a “typical” item
  - put it in a loop

Algorithm design using iteration

```
public void drawBubbles(double x, double y, int n){
    for (int i = 0; i<n; i++ ) {
        this.drawBubble(x, y, 15);
        y = y - 20;
    }
}

public void drawBubble(double x, double y, double size){
    UI.setColor(Color.blue);
    UI.fillOval(x, y, size, size);
}
```

Algorithm Design with Recursion

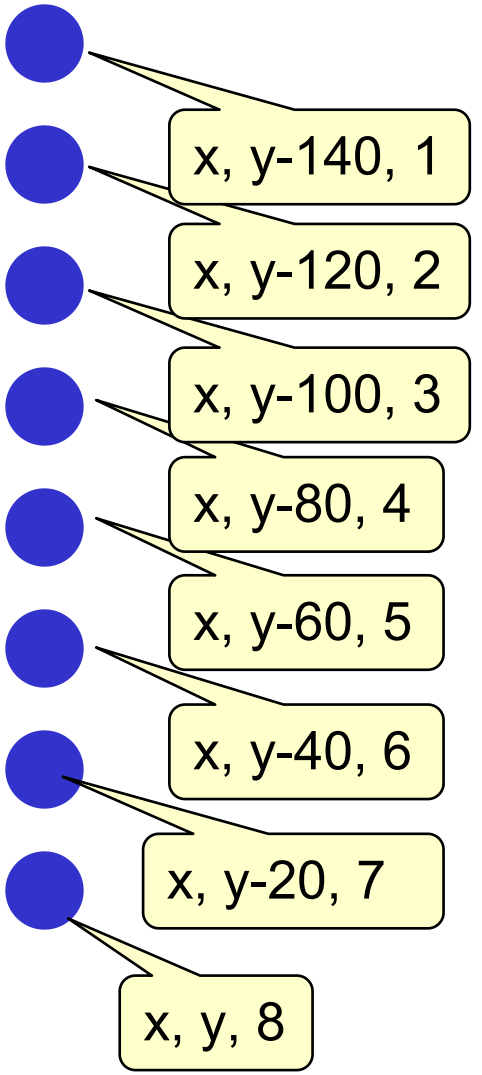
Break up a problem into “the first” and “the rest”

- where “the rest” is a smaller version of the same problem.
  - ! can use the same method:

```
public void drawBubbles(double x, double y, int n){
    // draw one bubble
    this.drawBubble(x, y, 15);
    // if there are any remaining bubbles
    if ( n > 1 )  {
        // draw them
        this.drawBubbles(x, y-20, n-1);
    }
}
```

Recursive call

Must have condition to prevent infinite recursion:
Need a “Base case” with no recursive call

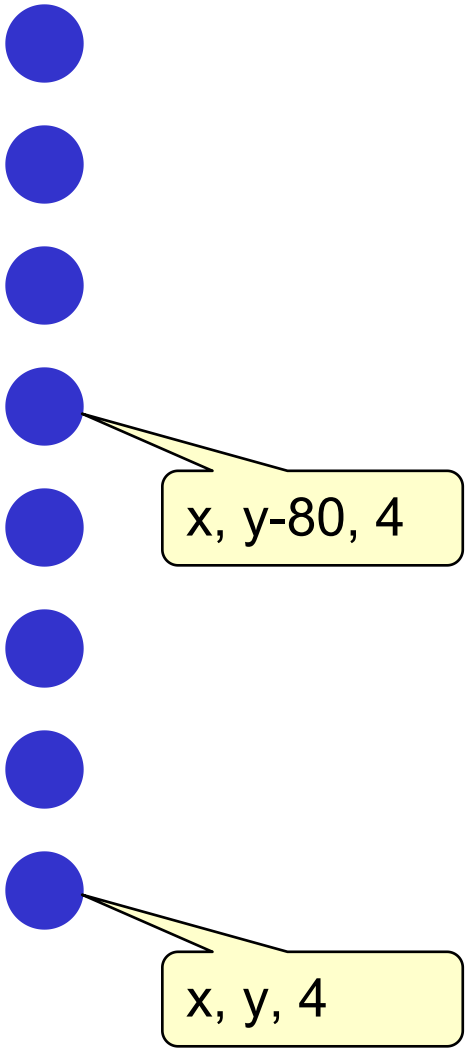


Algorithm Design with Recursion

Break up a problem into “first half” and “second half”

- where each half is a smaller version of the same problem.
  - ! can use the same method:

```
public void drawBubbles(double x, double y, int n){
    if ( n == 1 )   {
        this.drawBubble(x, y, 15);
    }
    else if ( n > 1 )   {
        this.drawBubbles(x, y, n/2);
        this.drawBubbles(x, y-n/2*20, (n – n/2));
    }
}
```



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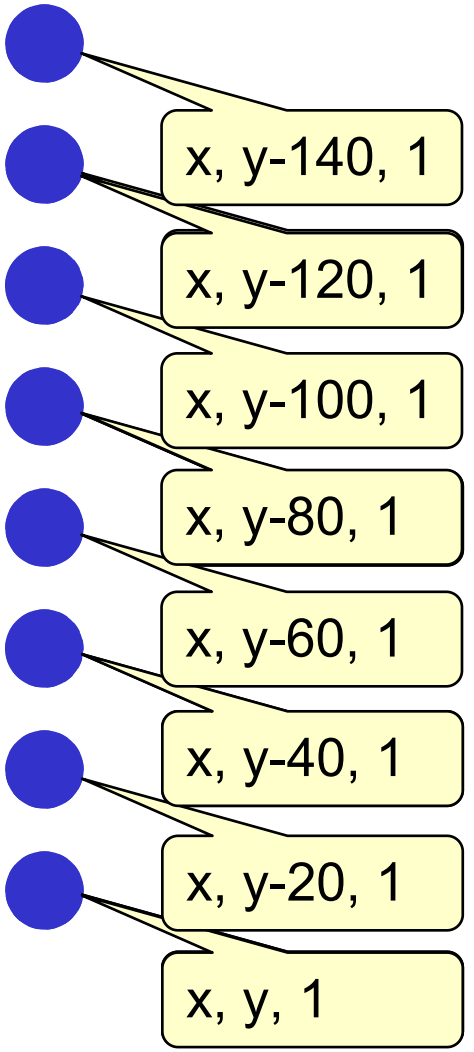
    }
}
```

x, y, 8



Recursion – An Example

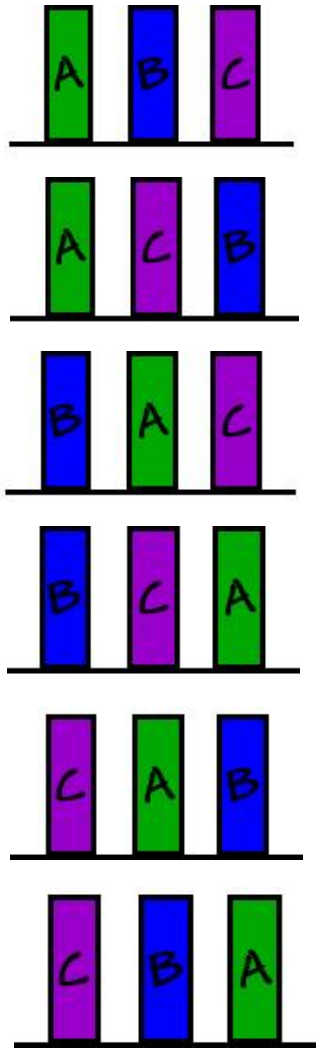
- How many ways are there to arrange n books in a line?
- This number is called *n factorial* and is usually written as **`n!`**
- Example: 3! = 3 * 2 * 1 = 6
- For any positive integer **`n`** it is defined as the product of all integers from 1 to n inclusive:

```
n! = n * (n-1) * (n-2) * ... * 3 * 2 * 1
```

- This definition can also be expressed recursively:

```
1! = 1
n! = n * (n-1)!
```

- That is, a factorial is defined in terms of another (smaller) factorial until the base case of 1! is reached
- Note: some mathematical formulas have a very elegant recursive definition



Factorial – Using Iteration

```
public int fact(int n){

    int result = 1;
    for (int  i = 1; i<=n; i++ ) {
        result *= i;
    }
    return result;
}

UI.println(fact(5));
```

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Factorial – Using Recursion

```
public int fact(int n){

    if (n == 1) return 1;

    return n * fact(n-1);
}


//The runtime system creates a stack of results
```

Recursion *vs* Iteration

- Iteration:
  - break problem into sequence of the typical case
  - identify the typical case (body)
  - identify the increment to step to the next case
  - identify the keep-going or stopping condition
  - identify the initialisation
- Recursion: (simple)
  - break problem into first and rest
  - identify the first case
  - identify the recursive call for the rest
    - work out the arguments for the rest
  - identify when you should do the recursive call.
    - make sure there is a stopping case (base case)
  - may need a wrapper method to initialise

```
public int fact(int n){

    int result = 1;
    for (int  i = 1; i<=n; i++ ) {
        result *= i;
    }
    return result;
}
```

```
public int fact(int n){

    if (n == 1) return 1;

    return n * fact(n-1);
}
```

“first” might be split in multiple parts

- Example: Print an “onion” : ((((((( )))))))

```
public void onion (int layers){
    UI.print( " (" );
    if (layers > 1)  {  this.onion(layers-1); }
    UI.print( " )" );
}
```

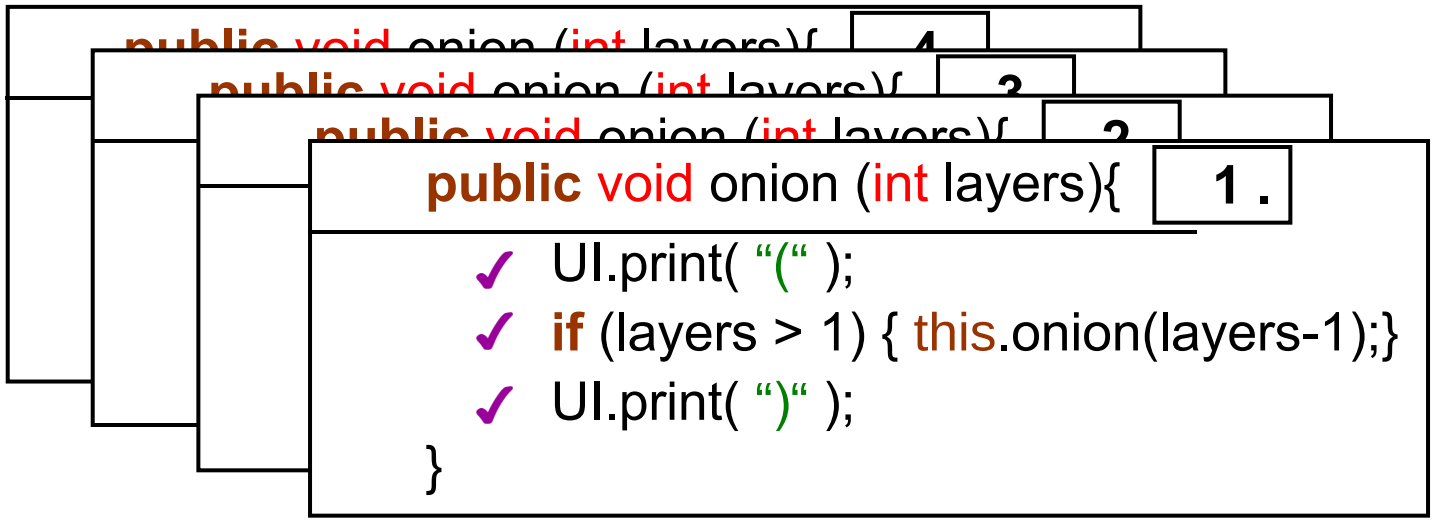
open

do the inside

close

Recursion at work

onion(4) ⇒ (((( ))))



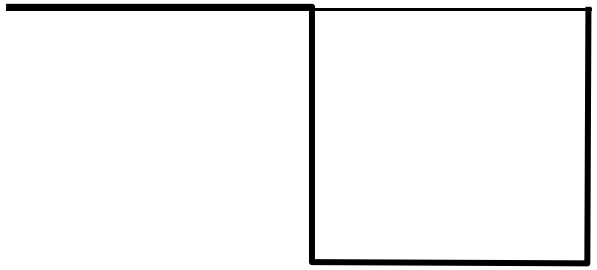

```
public void onion (int layers){
    UI.print( "(" );
    if (layers > 1)  { this.onion(layers-1); }
    UI.print( ")" );
}
```

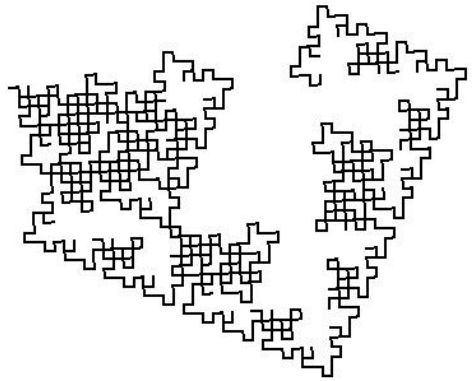
Recursion and Fractals

- Fractals are geometric patterns with repeated structure at multiple levels:

Simple examples:

- Fractal Line





- Sierpinski Triangle