Algorithm Design and Problem-solving

A-Level Computer Science

Computational thinking

Computational thinking 计算思维 is the set of mental tools for **analysing a problem and designing a solution a computer can run**. Two key ones are abstraction and decomposition.

Computational thinking breaks a big problem into smaller, easier parts —like solving a jigsaw

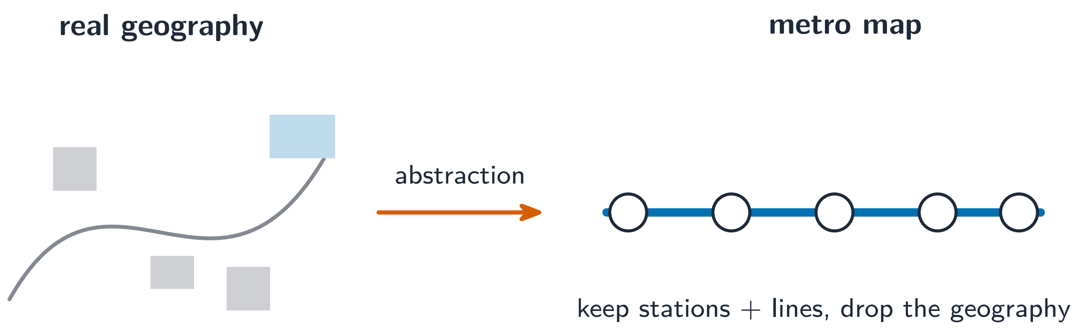
Abstraction

Abstraction 抽象 means **keeping the essential features** of a problem and **ignoring the irrelevant detail**, giving a simpler model.

Examples:

- a **train-network map** keeps the stations and lines but drops the geography.
- a **class** in object-oriented programming keeps only the attributes and methods the system needs.
- a **function** hides a piece of work behind a name.

A full model of any real problem would be too big to reason about, so abstraction is essential.



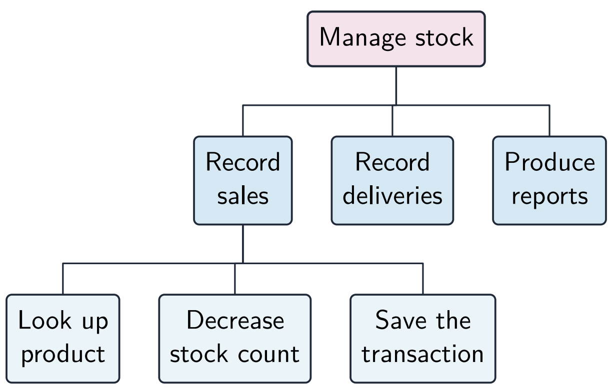
Abstraction keeps the essentials (stations and lines) and drops irrelevant detail (the geography)

Decomposition

Decomposition 分解 means **breaking a large problem into smaller sub-problems**, each easier to solve and tackled one at a time.

1. find the main parts of the task.
2. break each into smaller sub-tasks.
3. continue until each is small enough to design directly.
4. solve the small tasks and combine them.

For stock control: "manage stock" → "record sales", "record deliveries", "produce reports" → ("record sales") "look up product", "decrease stock count", "save the transaction". Decomposition makes big problems manageable, lets a team divide the work, and gives modular code —each module becomes a **procedure 过程** or function.



Decomposing a program into modules and sub-modules

Algorithms

An **algorithm 算法** is a **solution expressed as a sequence of defined steps**. Each step is **unambiguous 无歧义** (one meaning), **deterministic 确定性** (same input →

same output), **finite** (the steps end), and **effective** (each can be done). An algorithm says *what to do*, independent of the programming language used to implement it.

Identifier table

When you start an algorithm, list every piece of data in an **identifier table** 标识符表—its **variable** 变量 name, **data type** 数据类型, and description:

Variable name	Data type	Description
`Category`	`STRING`	the product category
`SaleDate`	`DATE`	when the item was sold
`ItemCost`	`REAL`	cost of the item
`InStock`	`BOOLEAN`	`TRUE` if in stock

Use **descriptive** names (`ItemCost`, not `x`); common types are `INTEGER`, `REAL`, `STRING`, `CHAR`, `BOOLEAN`, `DATE`, plus arrays. The table forces you to name every piece of data before writing code.

list every piece of data first - name, type, description

name	data type	description
`ItemCost`	`REAL`	cost of the item
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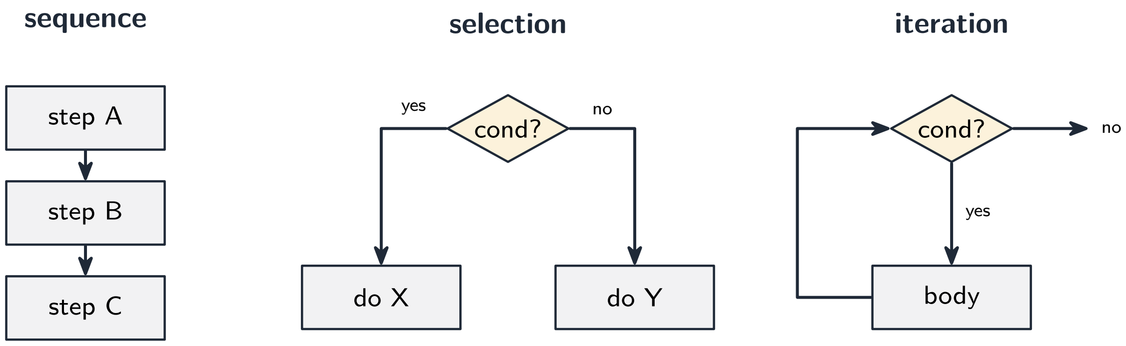
use **descriptive** names (`ItemCost`, not `x`) - the table forces you to plan the data

An identifier table names every piece of data before you write code

Pseudocode —the three basic constructs

Pseudocode 伪代码 is a structured, language-neutral way to describe algorithms.



The three building blocks of any algorithm: sequence, selection and iteration

1. Sequence

Steps run one after another (**sequence** 顺序):

```
INPUT Name
INPUT Age
OUTPUT "Hello", Name
```

2. Selection

A choice of which steps run, based on a condition (**selection** 选择):

```
IF Age >= 18 THEN
    OUTPUT "Adult"
ELSE
    OUTPUT "Minor"
ENDIF
```

For more options, use `CASE OF ... ENDCASE`.

3. Iteration

Repeating a block (**iteration** 迭代, a **loop** 循环):

```
FOR i ← 1 TO 10
    OUTPUT i
NEXT i
```

A **WHILE** loop tests the condition **before** each pass (may run zero times); a **REPEAT...UNTIL** loop tests **after** each pass (always runs at least once).

Common operations

- **assignment** 赋值: `x ← 5` (an arrow; `=` is for comparison).
- input/output: `INPUT variable`, `OUTPUT expression`.

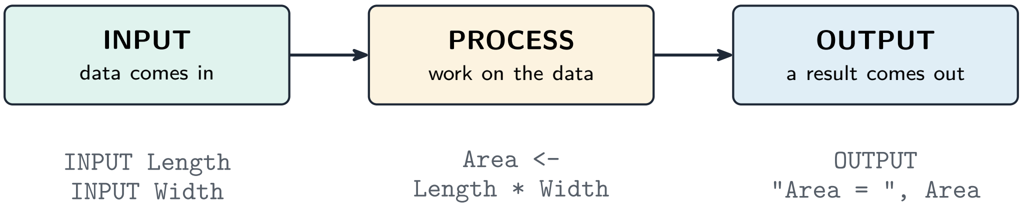
- comparisons `=`, `<>`, `<`, `>`, `<=`, `>=`; logic `AND`, `OR`, `NOT`.
- arithmetic `+ - * /`, plus `DIV` (integer division) and `MOD` (remainder).
- strings: `LENGTH`, `LEFT`, `RIGHT`, `MID`, and `&` for **concatenation** 拼接 (joining).

Input → Process → Output

Every program follows this shape:

```
INPUT Length
INPUT Width
Area ← Length * Width
OUTPUT "Area = ", Area
```

Listing the inputs and outputs first makes the algorithm cleaner.



Every program follows the Input, Process, Output shape

Three notations

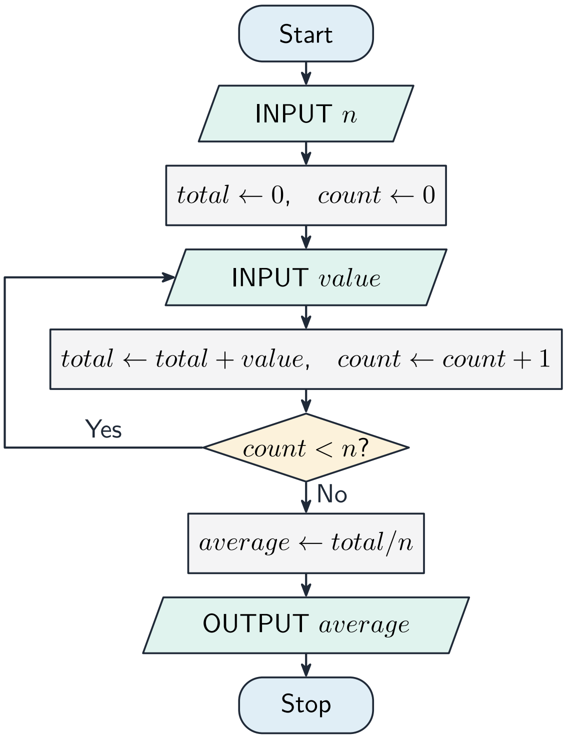
The same algorithm can be written three ways.

- **structured English** 结构化英语—natural language with indentation and fixed keywords; good for a high-level description.
- **flowchart** 流程图—a diagram with standard shapes:

Shape	Meaning
Rounded rectangle	Start / Stop
Parallelogram	Input / Output
Rectangle	Process
Diamond	Decision
Arrow	Flow of control

- **pseudocode** —the keyword notation above; closest to code.

You should be able to convert between any pair: each `IF` is a decision diamond, each loop is a back-arrow, and a sequence is stacked rectangles.



A flowchart for averaging a list of numbers, using the standard shapes

Stepwise refinement

Stepwise refinement 逐步求精 starts with a high-level outline and **expands each step** until it is small enough to code. For an average of n numbers:

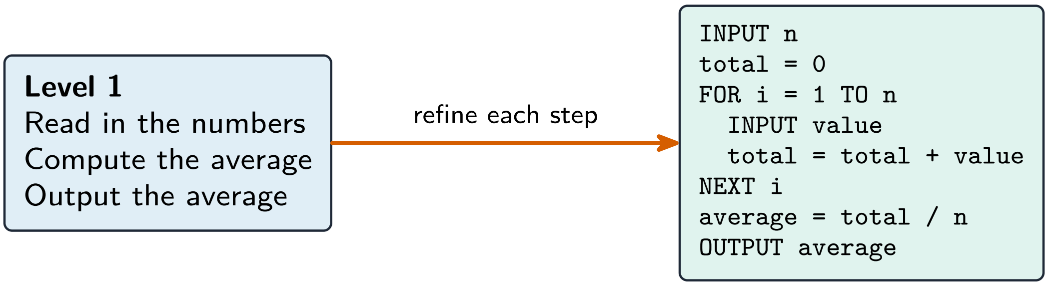
Level 1:

```
Read in the numbers
Compute the average
Output the average
```

Level 2:

```
INPUT n
total ← 0
FOR i ← 1 TO n
    INPUT value
    total ← total + value
NEXT i
average ← total / n
OUTPUT average
```

Each refinement keeps the previous structure and adds detail.



Stepwise refinement: expand each high-level step into detailed pseudocode

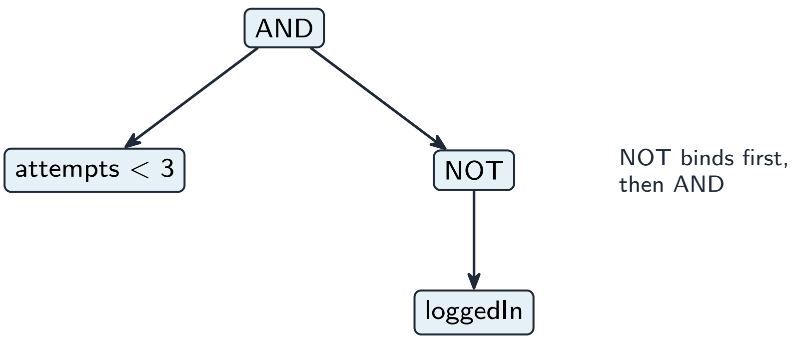
Logic statements

A **logic statement** 逻辑语句 is a **Boolean** 布尔 condition that controls branching, built from comparisons (`x > 10`), connectives (`AND`, `OR`, `NOT`) and brackets. Use it as the condition of `IF`, `WHILE` or `REPEAT...UNTIL`:

```
WHILE attempts < 3 AND NOT loggedIn DO
    INPUT password
    IF password = correctPassword THEN
        loggedIn ← TRUE
    ELSE
        attempts ← attempts + 1
    ENDIF
ENDWHILE
```

Precedence 优先级 (highest to lowest): `NOT`, then `AND`, then `OR`. Use brackets when unsure. Common mistakes:

- `a = 1 OR 2` is wrong —write `a = 1 OR a = 2`.
- `NOT a > 5` means `NOT (a > 5)`, i.e. `a <= 5`.
- `NOT (A AND B)` is the same as `(NOT A) OR (NOT B)` (**De Morgan's law** 德摩根定律) —handy for simplifying conditions.



Precedence: NOT binds to loggedIn first, then AND combines the two sides

Worked example. Write an identifier table and pseudocode to read 10 numbers and output the largest. The **identifier table** names each variable with its data type and purpose: `Count : INTEGER` (loop counter), `Num : REAL` (the number just read), `Max : REAL` (largest so far).

```
Max ← -999999
FOR Count ← 1 TO 10
    INPUT Num
    IF Num > Max THEN
        Max ← Num
    ENDIF
NEXT Count
OUTPUT Max
```

The design decision carrying the marks is **initialising `Max`**: it must start **lower than any possible input** - or, safer still, be set to the **first** number read. Initialise it to `0` and the algorithm wrongly returns 0 for a list of negative numbers, a bug your trace only exposes if the test data include a negative.

Exam tips

- Define an **algorithm** as an unambiguous, finite, deterministic sequence of steps, independent of language.
- Use the three constructs correctly —**sequence, selection, iteration** —and keep an identifier table with data types.
- Break a problem down by **decomposition and abstraction**, then stepwise refinement.
- Write pseudocode that would actually run: declare variables and follow the exam's pseudocode style.