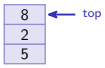
Data Types & Structures

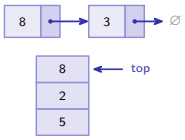
AS Computer Science ▪ Topic 10

A-Level Computer Science



What we will cover

1. Data types & records
2. Arrays
3. Files
4. Stacks, queues, linked lists
5. Implementing with arrays
6. Recap



1 Data types and records

Data types and records

Pick the smallest precise **data type** 数据类型:

- `INTEGER` – a whole number: counts, indexes, IDs
- `REAL` – has a fractional part: money, measurements
- `STRING` – characters in quotes, for text
- `CHAR` – one character; `BOOLEAN`; `DATE`

A **record** 记录 groups several types under one name (dot notation `Item1.Category`).

record TStockItem

`ItemID : INTEGER`
`Category : STRING`
`ItemCost : REAL`
`InStock : BOOLEAN`

one name holds four fields of different types

`reach one field: Item1.Category`

Choosing a data type, and when to use a record

`INTEGER` / `REAL`	a whole number; one with a fractional part
`CHAR` / `STRING`	a single character; a sequence of them
`BOOLEAN`	`TRUE` or `FALSE` – for flags
`DATE`	so dates sort and compare correctly
a record structure 记录结构	a group of fields of *different* types, under one name
when to use one	when the values always belong together – a customer, a stock item. Use separate variables for unrelated values

> An array holds many of the same type; a record holds one of several types. Most real data needs an array *of* records.

2 Arrays

Arrays

An **array** 数组 holds many values of the same type under one name, reached by an **index** 索引. A **record** 记录 is the opposite: different types, always belonging together.

1-D

8	3	5	1
1	2	3	4

2-D – `[row, column]`

2	7	4
2	7	4

1-D arrays

One index. `Marks[3]` is the third element – but check the lower bound: Cambridge pseudocode usually starts at 1, most languages at 0.

index	[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
`myList`	27	19	36	42	16	89	21	16	55

lower bound (first index) — upper bound (last index)

Array vocabulary, and the standard sweep

index 索引	the position of an element within the array
bounds 边界	the lowest and highest valid indices – going outside them is an error
dimension 维度	how many indices are needed: 1-D for a single sequence, 2-D for a table
a 2-D array	the first index is the row, the second the column; nested loops visit every cell
to traverse 遍历	visit every element in turn
the sweep pattern	to find a sum, count, maximum or minimum, set a running variable before the loop and update it inside

The running variable must be initialised outside the loop. Inside, it resets every pass – the single commonest bug in this topic.

2-D arrays: a table

Two indices, row first: `Grid[2,5]` is row 2, column 5.

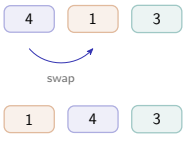
column index

row index	$[r,1]$	$[r,2]$	$[r,3]$	$[r,4]$
$[1,c]$	12	31	17	48
$[2,c]$	19	67	99	29
$[3,c]$	42	22	95	61

`Grid[2,3]` (row 2, column 3)

Searching and sorting

Linear search walks from the start until it finds the target – works on any list, $O(n)$. **Bubble sort** swaps adjacent pairs that are out of order, so the largest "bubbles" to the end each pass – $O(n^2)$.



One pass of a bubble sort

One pass of a bubble sort: adjacent pairs are compared and swapped, bubbling the largest value to the end

5 2 8 1	start
2 5 8 1	compare 5, 2 → swap
2 5 8 1	compare 5, 8 → already in order
2 5 1 8	compare 8, 1 → swap (8 reaches the end)

Worked example: find the largest

```
DECLARE Marks : ARRAY[1:4] OF INTEGER
Max ← Marks[1]
FOR i ← 2 TO 4
  IF Marks[i] > Max THEN
    Max ← Marks[i]
  ENDIF
NEXT i
OUTPUT Max
```

[1]	[2]	[3]	[4]
7	3	9	2

i	Marks[i]	Max
–	–	7
2	3	7
3	9	**9**
4	2	9

output: **9**

Start `Max` at the first element, not at 0 – then compare from the second.

Files

RAM (variables) lost when the program ends → save / load → file on disk kept between runs

A **file** 文件 keeps data on disk between runs (RAM is lost at exit).

- `OPENFILE` for READ/WRITE/APPEND
- `EOF` tests the **end of file** 文件结束
- always `CLOSEFILE` – or buffered writes are lost

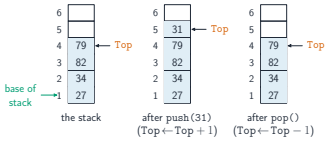
Files, stacks and queues

a file 文件	data on **secondary storage** 辅助存储器, kept between program runs
why needed	variables live in RAM and disappear when the program stops
a text file 文本文件	read and written line by line, and readable by a person
a stack	add and remove at the top only – LIFO. A pile of books: the last one on is the first one off
a queue	join at the back, served from the front – FIFO. Whoever waited longest is served first
the operations	stack: push and pop. Queue: enqueue and dequeue. Both need an empty and a full check

> Choose by which end you need: undo history and call returns are stacks; print jobs and buffers are queues.

3 ADTs

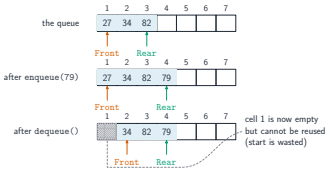
Abstract data types: the stack



A **stack** 栈 is **LIFO** 后进先出: push and pop happen at the top – undo history, procedure calls.

A stack is last-in, first-out

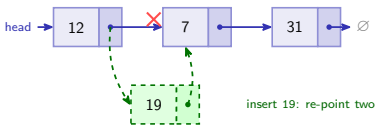
Abstract data types: the queue



A **queue** 队列 is **FIFO** 先进先出: enqueue at the back, dequeue at the front – print **spooling** 排队打印, scheduling.

A queue is first-in, first-out

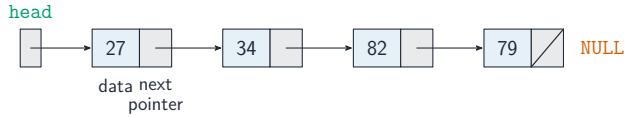
Linked list



A **linked list** 链表 chains **nodes** 节点, each a value + a **pointer** 指针 to the next.

- \+ cheap insert/delete – nothing shifts
- − slow random access

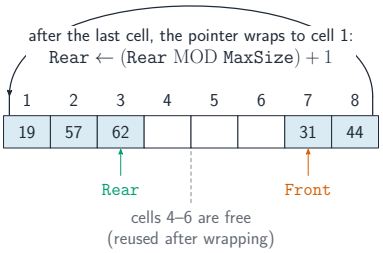
A linked list, drawn out



Each node carries its data and a pointer to the next; the last points at null.

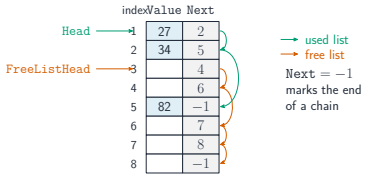
4 Implementing

ADTs with arrays



- stack: a `Top` index; full = **overflow** 溢出, empty = **underflow** 下溢
- queue: a **circular array** 循环数组 – pointers wrap with `(p MOD MaxSize) + 1`

Linked list in an array



Store nodes in an array of records, each with a `Next` index. A **free list** 空闲列表 chains the unused slots – linked-structure flexibility with static allocation.

Worked example – a circular queue

A circular queue in an array of size 5 has `Front = 3`, `Rear = 3` and one item. Two items are added, then two removed. Where are the pointers?

- Every move is `(pointer + 1) MOD size`, so the pointers **wrap**.
- Adding twice moves `Rear`: $3 \to 4 \to 0$ (since $(4+1) \bmod 5 = 0$), leaving `Rear = 0` and three items stored.
- Removing twice moves `Front` the same way, leaving `Front = 0` and one item.

The wrap is the point: in a linear array queue the pointers march to the end and the freed space at the front can never be reused.

Exam tips

- Choose the right **data structure** and justify it (a record for mixed fields, a 2-D array for a grid).
- Know how to implement a **stack, queue and linked list** with an array and pointers (top; front/rear; next).
- Distinguish an **ADT** (its behaviour) from its implementation (array plus pointers).

5 Recap

Topic 10 – key takeaways

1. **Records & arrays** — records mix types; arrays hold one type
2. **Files** — persist data; open, read/write, close
3. **Stack & queue** — LIFO vs FIFO
4. **Linked list** — nodes with pointers; cheap insert/delete

Check yourself

1. Which holds several different types together?
2. Which ADT is FIFO?
3. Why use a circular array for a queue?
4. One advantage of a linked list over an array?

Answers **1.** a record **2.** a queue **3.** reuse the wrapped-round cells **4.** cheap insertion/deletion