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Sorting

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❖ Sorting

Sorting involves arranging a collection of items in order

- based on some property of the items (e.g. key)
- using an ordering relation on that property

Why is sorting useful?

- speeds up subsequent searching
- arranges data in a human-useful way
  (e.g. list of students in a tute class, ordered by family-name or id)
- arranges data in a computationally-useful way
  (e.g. duplicate detection/removal, many DBMS operations)

❖ ... Sorting

Sorting occurs in many data contexts, e.g.

- arrays, linked-lists   (internal, in-memory)
- files   (external, on-disk)

Different contexts generally require different approaches

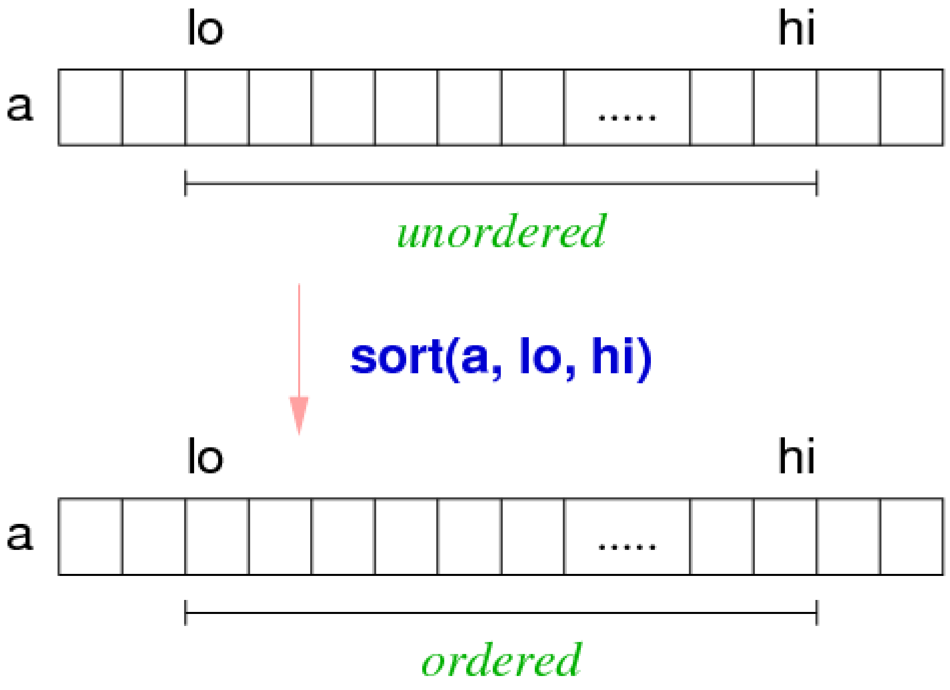
- and sorting has been well-studied over the last 50 years

Our view of the sorting problem:

- arrange an array of `Item`s in ascending order
- could sort whole array, or could sort a slice of the array

❖ The Sorting Problem

Arrange items in array slice **`a[lo..hi]`** into sorted order:



For **`Item a[N]`**, frequently **`(lo == 0)`**, **`(hi == N-1)`**

❖ ... The Sorting Problem

More formally ...

Precondition:

- **`lo`**,**`hi`** are valid indexes, i.e. **`0`** ≤ **`lo`** < **`hi`** ≤ **`N-1`**
- **`a[lo..hi]`** contains defined values of type **`Item`**

Postcondition:

- **`a[lo..hi]`** contains same set (bag) of values
- foreach **`i`** in **`lo..hi-1`**, **`a[i]`** ≤ **`a[i+1]`**

❖ ... The Sorting Problem

We sort arrays of **`Item`**s, which could be

- simple values, e.g. **`int`**, **`char`**, **`float`**
- structured values, e.g. **`struct`**

Each **`Item`** contains a **`key`**, which could be

- a simple value, or a collection of values

The order of **`key`** values determines the order of the sort.

Duplicate **`key`** values are not precluded.

In our discussions, we often use the **`key`** value as if it is the whole **`Item`**

❖ ... The Sorting Problem

Properties of sorting algorithms: stable, adaptive

Stable sort:

- let x = **`a[i]`**, y = **`a[j]`**, **`key(x) == key(y)`**
- "precedes" = occurs earlier in the array (smaller index)
- if x precedes y in **`a`**, then x precedes y in sorted **`a`**

Adaptive:

- behaviour/performance of algorithm affected by data values
- i.e. best/average/worst case performance differs

❖ ... The Sorting Problem

In analysing sorting algorithms:

- N = number of items = **`hi-lo+1`**
- C = number of comparisons between items
- S = number of times items are swapped

Aim to minimise C and S

Cases to consider for initial order of items:

- random order: **`Items`** in **`a[lo..hi]`** have no ordering
- sorted order: **`a[lo]`** ≤ **`a[lo+1]`** ≤ ... ≤ **`a[hi]`**
- revserse order: **`a[lo]`** ≥ **`a[lo+1]`** ≥ ... ≥ **`a[hi]`**

❖ Comparison of Sorting Algorithms

A variety of sorting algorithms exist

- most are in-memory algorithms, some also work with files
- two major classes: $O(n^2)$, $O(n \log n)$
- $O(n^2)$ are acceptable if n is small (hundreds)

Ways to compare algorithms:

- implement and monitor performance
- graphic visualisations
- or even folk dancing

❖ Implementing Sorting

Concrete framework:

```
// we deal with generic Items
typedef SomeType Item;

// abstractions to hide details of Items
#define key(A) (A)
#define less(A,B) (key(A) < key(B))
#define swap(A,B) {Item t; t = A; A = B; B = t;}

// Sorts a slice of an array of Items, a[lo..hi]
void sort(Item a[], int lo, int hi);

// Check for sortedness (to validate functions)
int isSorted(Item a[], int lo, int hi);
```

❖ Implementing `isSorted()`

Implementation of the **`isSorted()`** check.

```
bool isSorted(Item a[], int lo, int hi)
{
   for (int i = lo; i < hi; i++) {
      if (!less(a[i],a[i+1])) return false;
   }
   return true;
}
```

Checks pairs (**`a[lo]`**,**`a[lo+1]`**), ... (**`a[hi-1]`**,**`a[hi]`**)

Check whole array **`Item a[N]`** via **`isSorted(a, 0, N-1)`**

❖ Sorts on Linux

The `sort` command

- sorts a file of text, understands fields in line
- can sort alphabetically, numerically, reverse, random

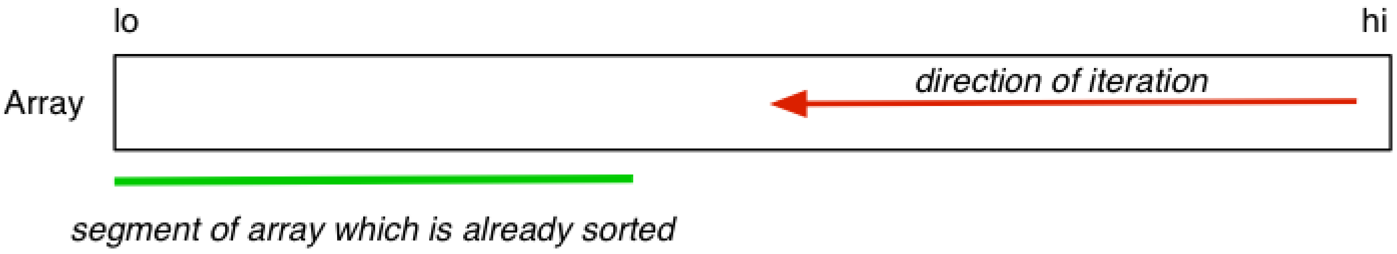
The `qsort()` function

- `qsort(void *a, int n, int size, int (*cmp)())`
- sorts any kind of array (`n` objects, each of `size` bytes)
- requires the user to supply a comparison function (e.g. `strcmp()`)
- sorts list of items using the order given by `cmp()`

Note: the comparison function is passed as a parameter; discussed elsewhere.

❖ Describing Sorting Algorithms

To describe sorting, we use diagrams like:



In these algorithms ...

- some part(s) of the array is already sorted
- each iteration makes more of the array sorted

See also animations by David R. Martin, Boston College, based on Sedgewick's idea