Lecture 7: ArrayList Implementation & Complexity

CS 62

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Lab

- Timing `ArrayList` operations
- Encourage working in pairs
- `Stopwatch` class: `start()`, `stop()`, `getTime()`, `reset()`
- Java has Just-In-Time compiler
- Must "warm-up" before you get accurate timing
  - What can mess up timing?
- Uses `Vector` from Bailey rather than `ArrayList` from Java libraries because can change way it increases in size.

Programming Assignment

- Weak AI/Natural Language Processing:
- Generate text by building frequency lists based on pairs of words. `ArrayList` of `Associations` of `String` (words) and `Integer` (count of that word)
- https://pdos.csail.mit.edu/archive/scigen/

Random Number Generator

- class `Random` in `java.util` package w/ method
  - `int nextInt(int n)` -- returns random k s.t. $0 \leq k < n$
  - `int nextDouble()` -- returns random k s.t. $0 \leq k < 1$
  - See bottom of pg 30 in text.

- Create `Random` object once:
  - `Random rng = new Random();`
- send `nextDouble` many times:
  - `double r = rng.nextDouble();`
  - Repeat this step, not the creation of a new object

- See `Lab1` example.

ArrayList

- Not using Bailey implementation
  - see code on-line for implementation by Tamassia & Goodrich
- Standard Java libraries have lots of extra methods not in our implementation
- Many involve working on other collections
  - irrelevant for us at this point.
  - `addAll`, `clear` , `contains` , `containsAll` , `listIterator`, `removeAll` , `replaceAll` , `retainAll` , `sort` , `spliterator`, `sublist` , `toArray`

Generics

- Enable classes and interfaces to be parameters to classes, interfaces, and methods.
  - No need for casting
  - Stronger type check

  - `class Name<T1, T2, ..., Tn> {…}`
  - `T` can be used anywhere within the class
  - `T` can be class or interface

- `T` →Type, `E` →Element (common for data structures), `K`→ Key, `V`→Value, `N`→number

- See **`Association`** class in Bailey `structure5` library
  - `public class Association<K,V>`
  - `Association<String, Integer> phoneBook = new Association<String, Integer> ();`

Tamassia & Goodrich `ArrayList`

- Interface is `IndexList<E>`
- See `ArrayIndexList<E>`
  - Similar to `ArrayList`
  - Instance variables:
    - `elts`: array instance variable
    - `eltsFilled`: number of slots filled.
- Creating new `ArrayList` is weird
  - Can't construct array of variable type!
  - Create array of `Object`, but coerce to believe array of `E`

`ArrayList` Implementation

- Some operations very cheap:
  - `size, isEmpty, get, set` take constant time (no search)
  - Others more expensive

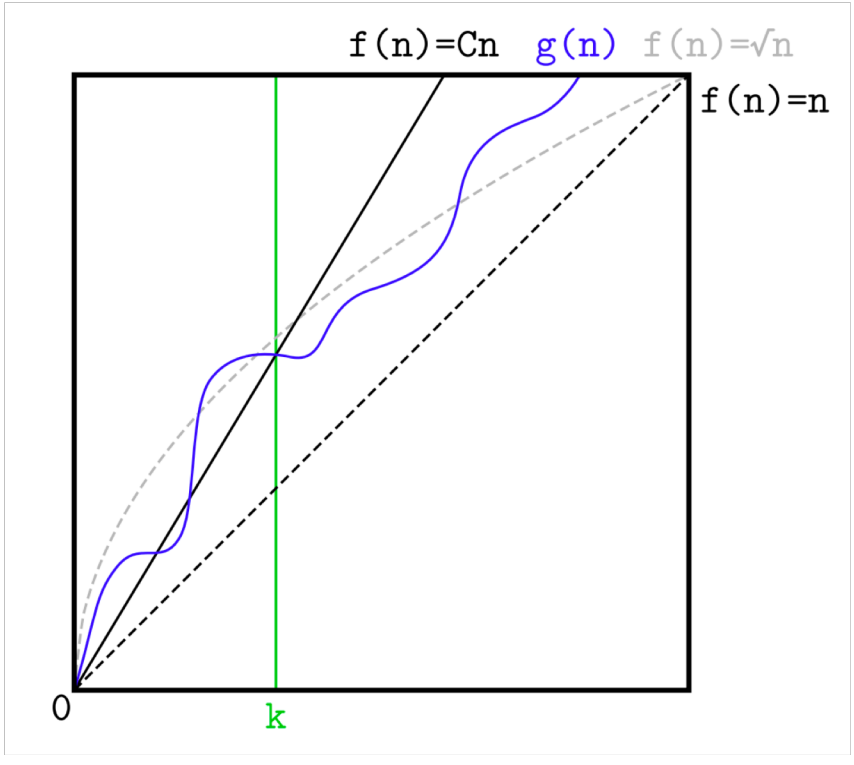
Adding Elts in Slot i

- Easy if there is space:
  - At end, just add it
  - If before end, must move all elements at i and beyond to right before inserting
  - *Delete similar*
- What if we run out of space?
  - Create new array twice as big and copy old elements over before adding.
  - How expensive is this?

Order of Magnitude

- Definition: We say that $g(n)$ is $O(f(n))$ if there exist two constants C and k such that
$$|g(n)| <= C\,|f(n)|, for\ all\ n > k.$$
- Used to measure time and space complexity of algorithms on data structures of size n.
- Examples:
  - $2n + 1$ is $O(n)$
  - $n^3 - n^2 + 83$ is $O(n^3)$
  - $2^n + n^2$ is $O(2^n)$
- Most common are:
  - $O(1)$ - for any constant
  - $O(\log n), O(n), O(n \log n), O(n^2), \ldots, O(2^n)$

Complexity



Complexity

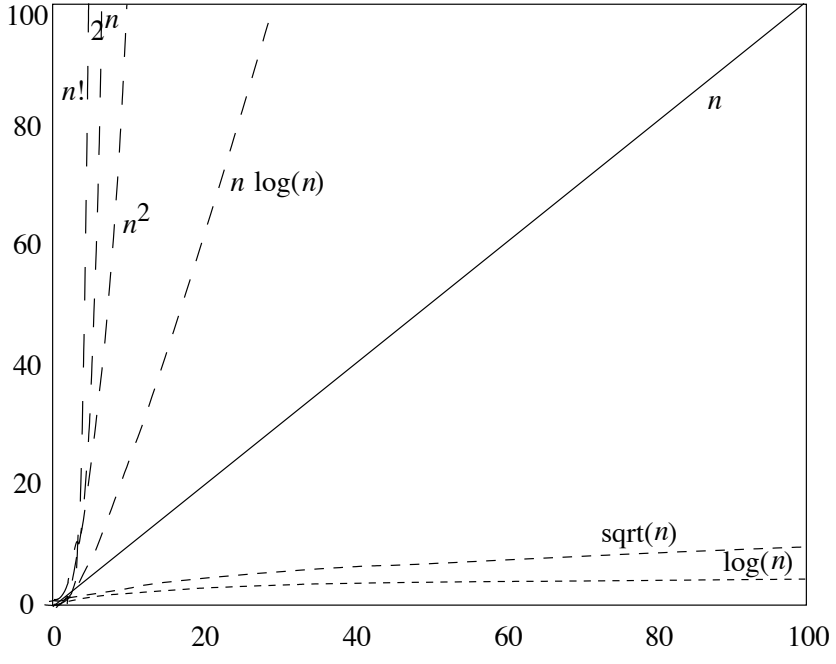


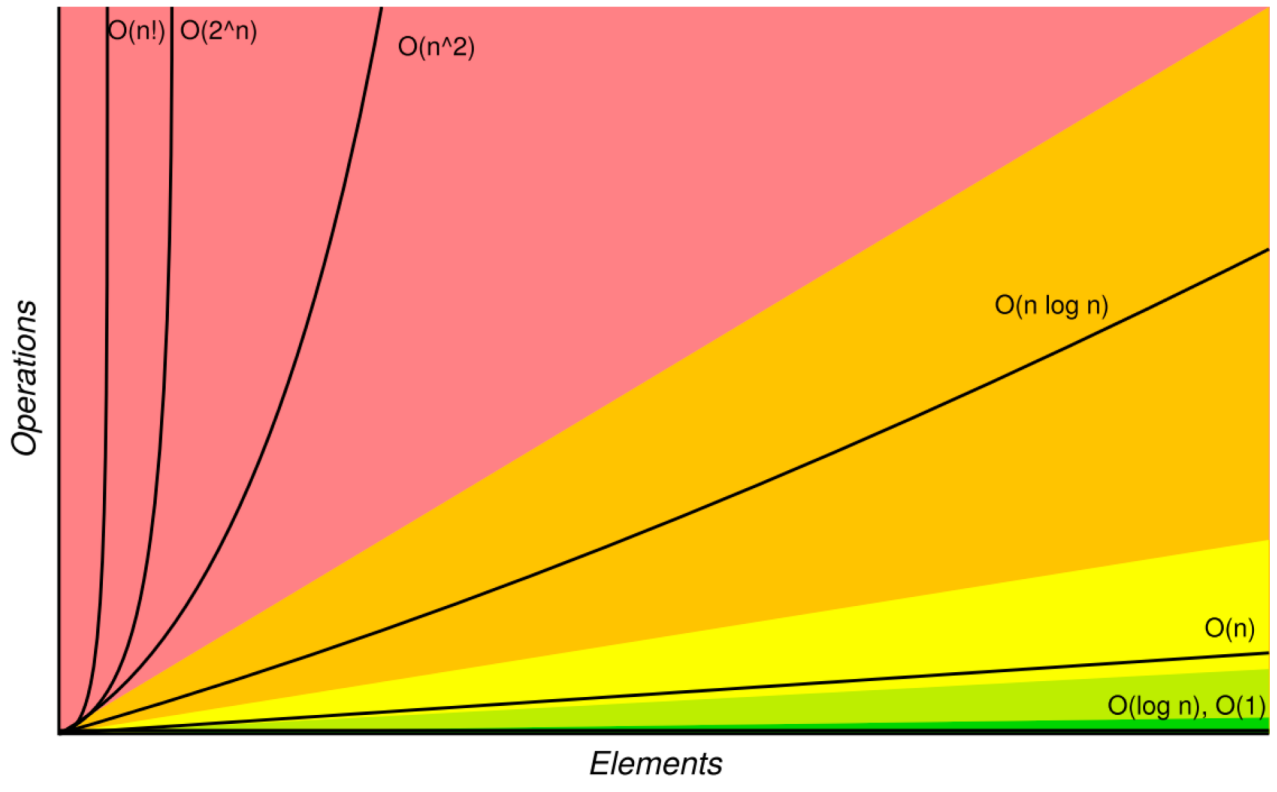
Figure 5.3 Long-range trends of common curves. Compare with Figure 5.2.

Comparing Orders of Magnitude

- Suppose have ops w/complexities given & problem of size n taking time t.
- How long if increase size of problem?

Problem Size:	*10 n*	*100n*	*1000n*
$O(\log n)$	3+t	7 + t	10+ t
$O(n)$	10 t	100 t	1000 t
$O(n \log n)$	> 10 t	> 100 t	> 1000 t
$O(n^2)$	100 t	10,000 t	1,000,000 t
$O(2^n)$	~ t^{10}	~ t^{100}	~ t^{1000}

Rule of thumb



bigocheatsheet.com

Adding to `ArrayList`

- Suppose n elements in `ArrayList` and add 1.
- If space:
  - Add to end is $O(1)$
  - Add to beginning is $O(n)$
- If not space:
  - What is cost of `ensureCapacity`?
  - $O(n)$ because n elements in array

EnsureCapacity

- What if only increase in size by 1 each time?
  - Adding n elements one at a time to end
    - Total cost of copying over arrays: $1 + 2 + 3 + \cdots + (n-1) = n(n-1)/2$
    - Total cost of $O(n^2)$
  - Average cost of each is $O(n)$

- What if double in size each time?
  - Suppose add $n = 2^m$ new `elts` to end
    - Total cost of copying over arrays: $1 + 2 + 4 + \cdots + n/2 = n - 1, O(n)$
    - Average cost of $O(1)$, but "lumpy"

`ArrayList` Operations

- Worst case:
  - $O(1)$: `size, isEmpty, get, set`
  - $O(n)$: `remove, add`

- Add to end is on average $O(1)$