Data Structures & Algorithms Coursework

Ricard Solé Casas

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Declaration

Acknowledgements

I'd like to thank my partner Shannon for her continued support and challenges that help me grow, both professionally and personally. I would also like to thank all of you who also helped me get here.

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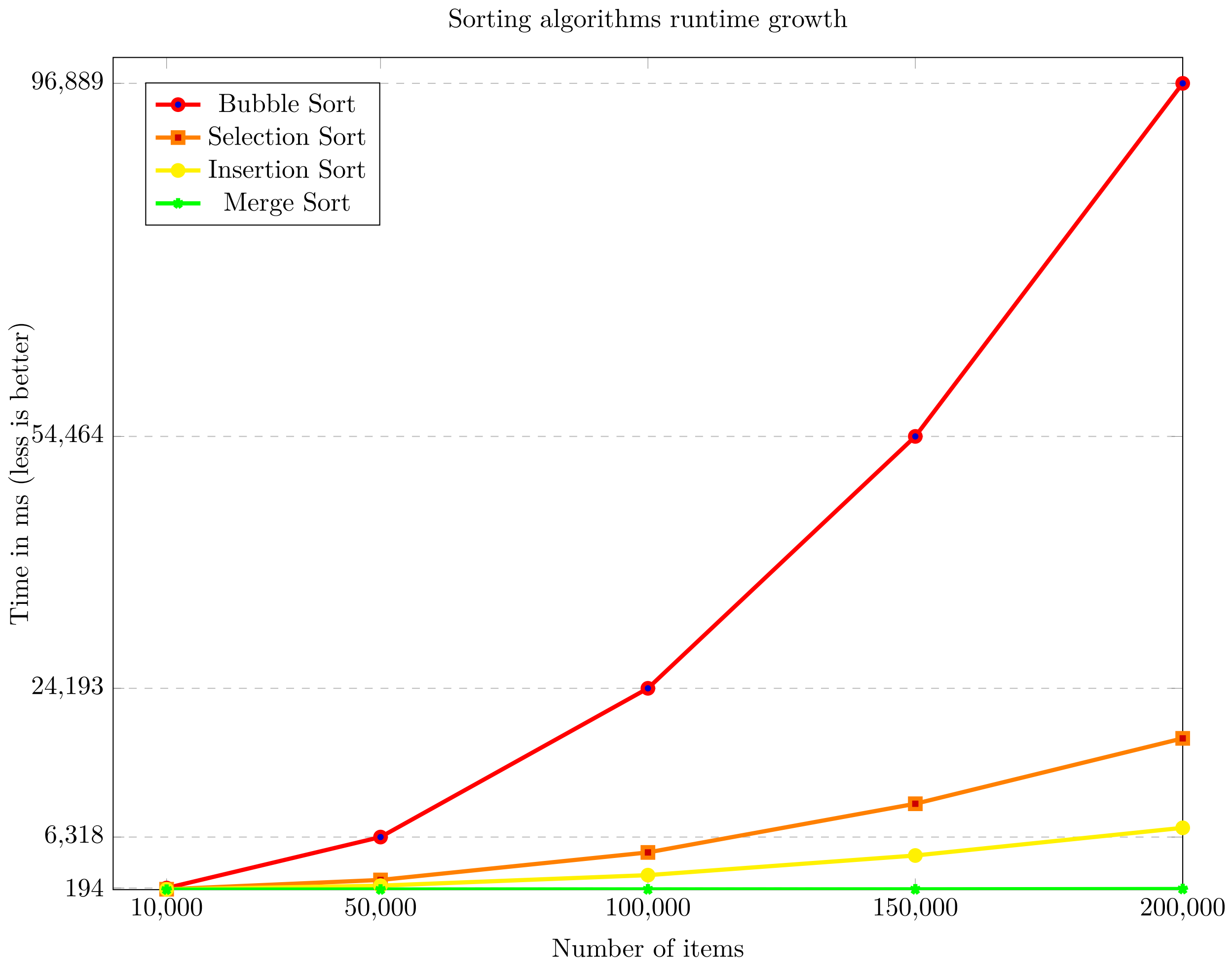
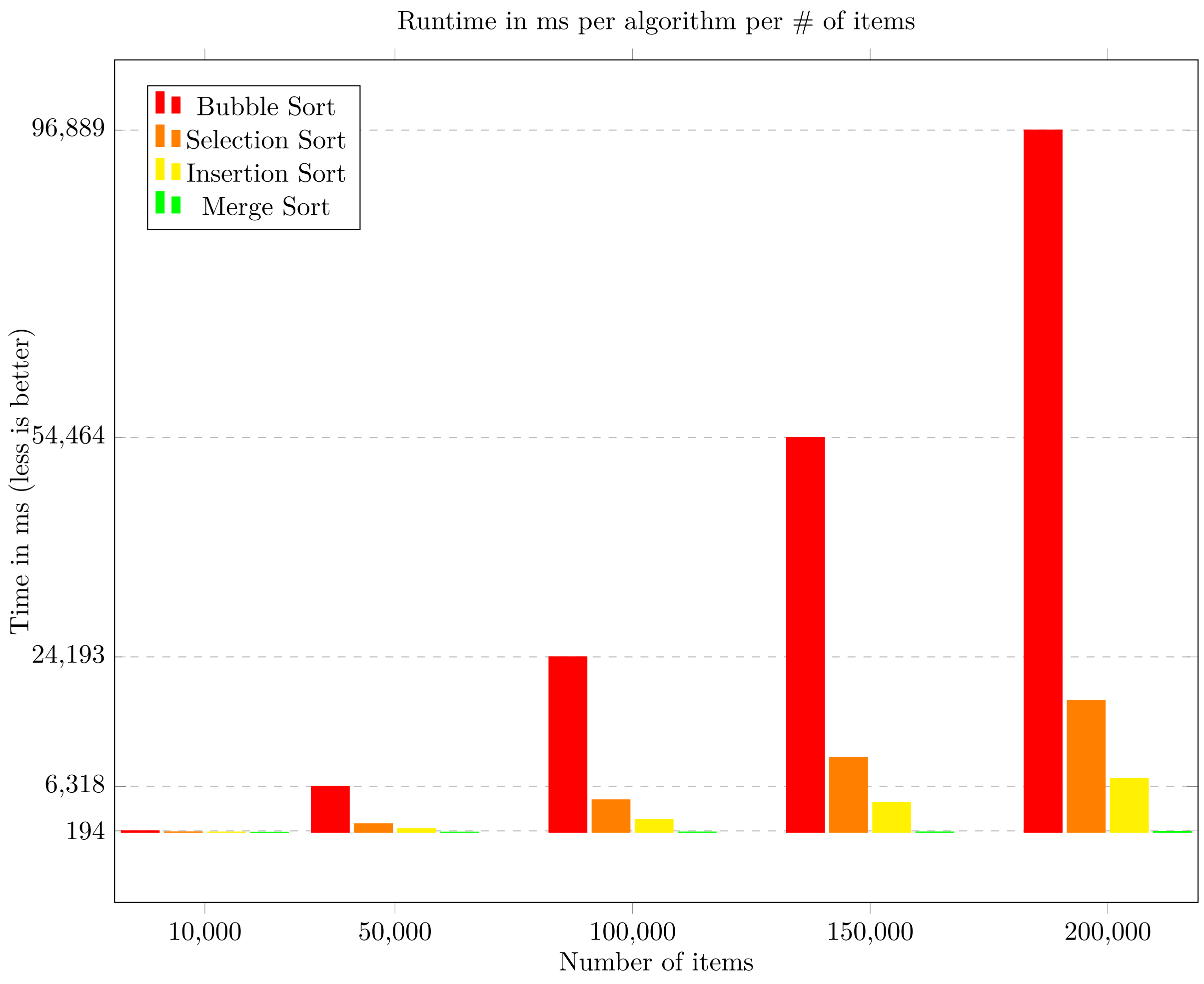
Chapter 1

Analysis of Sorting Algorithms

1.1 Sort time growth



1.2 Runtime Comparison



1.3 Reflection[1]

We know that the complexity for the algorithms benchmarked above —$O(n^2)$, $O(n^2)$, $O(n^2)$ and $O(n\log_2(n))$ respectively—, and we can see that mapped accurately in the plots above.

The first plot, the graph displayed on section 1.1, shows the increment in time for the *bubble*, *selection*, and *insertion* sort algorithms as exponential. Their curves vary greatly because `Big O` is not meant to give an accurate description of the time, just of how it'll scale. The point being, they all scale in a similar manner. The green line represents the *merge* sort algorithm which is, along with *quicksort*, considered to be the best algorithm overall. We can barely see it scale because the plot is drawn next to the quadratic plot of *bubble* sort. If we look closely, though, we can see it almost resembles a linear time complexity, but not quite.

The second plot, a bar graph displayed on section 1.2, uses the same colors and the same data to represent, perhaps more clearly, how each algorithm fairs amongst each other using the same dataset.

[1]Selection sort and benchmark utility code can be found Appendix A.

Chapter 2

Segregate Even and Odd numbers

2.1 Task

Given an array `A[]`, write an algorithm in pseudocode that segregates even and odd numbers. The algorithm should put all even numbers first, and then odd numbers.

2.2 Implementation

```haskell
module Main where

list :: [Int]
list = [12, 34, 45, 9, 8, 90, 3, -1000, -1001]

main :: IO ()
main = print (isolate list)

isolate :: (Integral a) => [a] -> [a]
isolate xs =
  evens xs ++ odds xs -- O(2n + m)

evens :: (Integral a) => [a] -> [a] -- O(n)
evens = filter even

odds :: (Integral a) => [a] -> [a] -- O(n)
odds = filter odd
```

2.3 Complexity analysis

For the algorithm implemented in section 2.2:

- `filter`ing through an array for `even` or `odd` numbers has a complexity of $O(n)$, where n is the length of the given list.
- `(++)` has a complexity of $O(m)$[1], where m is the length of the second list.
  - $m = length(odds(xs))$ in our case
- With this we can conclude that the complexity of this algorithm is $O(2n + m)$, which can be simplified to $O(n + m)$.

[1] https://goo.gl/yZu7Ig

Chapter 3

Recursion

3.1 Tasks

Design a recursive method for each of the following problems:

1. When you cut a pizza, you cut along a diameter of the pizza. Let `pizza(n)` be the number of slices of pizza that exist after you have made `n` cuts, where `n ≥ 1`. For example, `pizza(2) = 4` because there are four slices after two diagonal cuts. Write a recursive method `pizza(n)` to return the number of slices and verify the correctness of your method when the pizza is cut 4 times *(3 points)*.

2. A bunch of motorcycles and cars want to parallel park on a street. The street can fit `n` motorcycles, but one car take up three motorcycle spaces. Let `a(n)` be the number of arrangements of cars and motorcycles on a street that fits n motorcycles *(7points)*.

Chapter 4

Appendix A

4.1 Benchmark.java

```java
package me.rsole.util;

import java.util.ArrayList;
import java.util.List;
import java.util.concurrent.TimeUnit;

public class Benchmark {
  private List<Thread> threads = new ArrayList<>();

  public void add(String name, Runnable computation) {
    Thread t = new Thread(
      () -> System.out.printf("%s took %s.\n", name, run(computation))
    );

    threads.add(t);
  }

  public void run() {
    for (Thread t : threads) t.run();
  }

  private String run(Runnable computation) {
    long start = System.currentTimeMillis();
    computation.run();
    long end = System.currentTimeMillis();

    return format(end - start);
  }

  private String format(long time) {
    long minutes = TimeUnit.MILLISECONDS.toMinutes(time);
    long seconds =
      TimeUnit.MILLISECONDS.toSeconds(time) -
      TimeUnit.MINUTES.toSeconds(minutes);
    long milliseconds =
      time -
      (TimeUnit.SECONDS.toMillis(seconds) +
      TimeUnit.MINUTES.toMillis(minutes));
    return String.format("%dm %ds %dms", minutes, seconds, milliseconds);
  }
}
```

4.2 SelectionSort.java

```
package me.rsole.sort;

import org.jetbrains.annotations.Contract;

public class SelectionSort {
  @Contract(pure = true)
  public static int[] exec(int[] xs) {
    int[] ys = xs.clone();
    int minIdx = 0;

    for (int i = 0; i < ys.length; i++) {
      for (int j = i; j < ys.length; j++) {
        if (ys[j] < ys[minIdx]) minIdx = j;
      }

      int swap = ys[i];
      ys[i] = ys[minIdx];
      ys[minIdx] = swap;
      minIdx = i + 1;
    }

    return ys;
  }
}
```