

CSE373: Data Structures and Algorithms

Bucket Sort and Radix Sort

Steve Tanimoto
Autumn 2016

This lecture material represents the work of multiple instructors at the University of Washington. Thank you to all who have contributed!

Sorting: The Big Picture

Surprising amount of neat stuff to say about sorting:

Simple algorithms: $O(n^2)$	Fancier algorithms: $O(n \log n)$	Comparison lower bound: $\Omega(n \log n)$	Specialized algorithms: $O(n)$	Handling huge data sets
Insertion sort Selection sort Shell sort ...	Heap sort Merge sort Quick sort ...		Bucket sort Radix sort	External sorting

Autumn 2016
CSE 373: Data Structures & Algorithms
2

Radix sort

- Origins go back to the 1890 U.S. census
- Radix = "the base of a number system"
 - Examples will use 10 because we are used to that
 - In implementations use larger numbers
 - For example, for ASCII strings, might use 128
- Idea:
 - Bucket sort on one digit at a time
 - Number of buckets = radix
 - Starting with *least* significant digit
 - Keeping sort *stable*
 - Do one pass per digit
 - Invariant: After k passes (digits), the last k digits are sorted

Autumn 2016
CSE 373: Data Structures & Algorithms
3

Example

Radix = 10

0	1	2	3	4	5	6	7	8	9
	721		3				537	478	9
			143				67	38	

Input: 478 537 9 721 3 38 143 67

First pass: bucket sort by ones digit

Order now: 721 3 143 537 67 478 38 9

Autumn 2016
CSE 373: Data Structures & Algorithms
4

Example

Radix = 10

0	1	2	3	4	5	6	7	8	9
	721		3				537	478	9
			143				67	38	

Order was: 721 3 143 537 67 478 38 9

Second pass: *stable* bucket sort by tens digit

Order now: 3 9 721 537 67 143 478 38

Autumn 2016
CSE 373: Data Structures & Algorithms
5

Example

Radix = 10

0	1	2	3	4	5	6	7	8	9
3		721	537	143		67	478		
9			38						

Order was: 3 9 721 537 38 143 67 478

Third pass: *stable* bucket sort by 100s digit

Order now: 3 9 38 67 143 478 537 721

Autumn 2016
CSE 373: Data Structures & Algorithms
6

Analysis

Input size: n

Number of buckets = Radix: B

Number of passes = "Digits": P

Work per pass is 1 bucket sort: $O(B+n)$

Total work is $O(P(B+n))$

Compared to comparison sorts, sometimes a win, but often not

- Example: Strings of English letters up to length 15
 - Run-time proportional to: $15 \cdot (52 + n)$
 - This is less than $n \log n$ only if $n > 33,000$
 - Of course, cross-over point depends on constant factors of the implementations
 - And radix sort can have poor locality properties

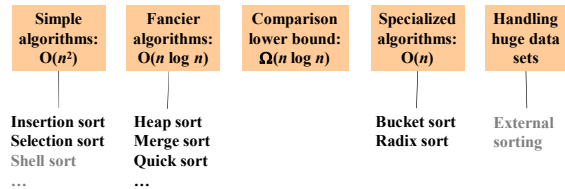
Autumn 2016

CSE 373: Data Structures & Algorithms

7

Sorting: The Big Picture

Surprising amount of neat stuff to say about sorting:



Autumn 2016

CSE 373: Data Structures & Algorithms

8

Last Slide on Sorting

- Simple $O(n^2)$ sorts can be fastest for small n
 - Selection sort, Insertion sort (latter linear for mostly-sorted)
 - Good for "below a cut-off" to help divide-and-conquer sorts
- $O(n \log n)$ sorts
 - Heap sort, in-place but not stable nor parallelizable
 - Merge sort, not in place but stable and works as external sort
 - Quick sort, in place but not stable and $O(n^2)$ in worst-case
 - Often fastest, but depends on costs of comparisons/copies
- $\Omega(n \log n)$ is worst-case and average lower-bound for sorting by comparisons
- Non-comparison sorts
 - Bucket sort good for small number of possible key values
 - Radix sort uses fewer buckets and more phases
- Best way to sort? It depends!

Autumn 2016

CSE 373: Data Structures & Algorithms

9

Done with sorting! (phew..)

- Moving on....
- There are many many algorithm techniques in the world
 - We've learned a few
- What are a few other "classic" algorithm techniques you should at least have heard of?
 - And what are the main ideas behind how they work?

Autumn 2016

CSE 373: Data Structures & Algorithms

10