

Linear and Binary Search

COMS10018 - Algorithms

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Runtime of Algorithms

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Worst-case Runtime: $\max_{X \in S(n)} T(X)$

Best-case Runtime: $\min_{X \in S(n)} T(X)$

Average-case Runtime: $\frac{1}{|S(n)|} \sum_{X \in S(n)} T(X)$

Linear Search:

- **Input:** Array A of n integers from range $\{0, 1, 2, \dots, k - 1\}$, for some integer k , integer $t \in \{0, 1, 2, \dots, k - 1\}$
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On any input with $A[0] = t$

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```

Average-case Runtime: (over all possible inputs of length n)

Average-case Analysis of Linear Search

Possible Inputs of Length n

$$S(n) := \{\text{arrays } A \text{ of length } n \text{ with } A[i] \in \{0, 1, 2, \dots, k-1\}, \\ \text{for every } 0 \leq i \leq n-1\}$$

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Auxiliary Function: For $A \in S(n)$, $t \in \{0, 1, \dots, k-1\}$:

$$\text{LEFT}(A, t) = \min\{i : A[i] = t\}.$$

If no such position exists then $\text{LEFT}(A, t) = n$.

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→ Linear search loop executed $\text{LEFT}(X, t) + 1$ times

Average-case Analysis of Linear Search (continued)

Average-case Runtime for $k = 2$: (binary strings)

We compute average number of steps the loop is executed ($t = 1$)

$$\text{AVG} = \frac{1}{|S(n)|} \sum_{A \in S(n)} \text{LEFT}(A, 1) + 1$$

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$$= 2^{-n} \left(\left(\sum_{i=0}^{n-1} 2^{n-1-i} \cdot (i+1) \right) + (n+1) \right) \rightarrow \text{AVG-case runtime is } O(1)$$

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$$\rightarrow S_n \leq 2$$

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Require: Sorted array A of length n , integer t

if $|A| \leq 2$ **then**

 Check $A[0]$ and $A[1]$ and **return** answer

if $A[\lfloor n/2 \rfloor] = t$ **then**

return $\lfloor n/2 \rfloor$

else if $A[\lfloor n/2 \rfloor] > t$ **then**

return $\text{BINARY-SEARCH}(A[0, \dots, \lfloor n/2 \rfloor - 1])$

else

return $\lfloor n/2 \rfloor + 1 + \text{BINARY-SEARCH}(A[\lfloor n/2 \rfloor + 1, n - 1])$

Algorithm BINARY-SEARCH

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Worst-case runtime of Binary Search: $O(\log n)$