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CPSC 320

PRE: $k \leq A.length$

QUICK-~~SORT~~ SELECT (A, k)
  if $|A| = 1$
    return $A[1]$
  else
    pick an a_i in A (i is index of some elt in A)
    Divide A into $A_L = [a_j \mid a_j < a_i \wedge a_j \in A]$
      and $A_R = [a_j \mid a_j > a_i \wedge a_j \in A]$

Assume all $a \in A$ are distinct

~~[QUICK-SORT(A_L)~~
~~[Quick-Sort(A_R)~~
~~return A_L ++ $[a_i]$ ++ A_R~~

if $A_L.length + 1 == k$
PIVOT IS IT! [return a_i
else if $A.length + 1 > k$
LOOK LEFT [return QUICK-SELECT(A_L, k);
else
LOOK RIGHT [return QUICK-SELECT(A_R, k-1-A_L.length

OK, so tag each a with its original position and break ties by tag.

WORST-CASE, a_i is an extreme element

$$T(n) = \underbrace{T(0)}_{\text{cut-out}} + \underbrace{T(n-1)}_{\text{all but pivot}} + \underbrace{cn}_{\text{partition}}$$

$$= T(n-1) + cn$$

$$= cn + c(n-1) + c(n-2) + \dots + c1$$

$$= c\frac{n(n+1)}{2} \in \Theta(n^2)$$

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BEST CASE. a_i is median

$$T(n) \le \cancel{2}T\left(\frac{n}{2}\right) + cn$$

MASTER THM

$a = 1$

$b = 2$

$f(n) = cn \in \Theta(n)$

~~$n^{\log_b a} = n^{\log_2 2} = n^1 = n$~~

$n^{\log_b a} = n^{\log_2 1} = n^0 = 1$

need $af\left(\frac{n}{5}\right) \le c'f(n)$

$af\left(\frac{n}{5}\right) = ac\frac{n}{5} \le \frac{ac}{6}n$ — c'

$f(n) \in \Omega\left(n^{\log_b a + 1}\right)$

~~$n^{\log_b a} \in \Theta(f(n))$~~ $O(f(n))$

~~$T(n) \in \Theta(n \lg n)$~~

~~and this is a comparison-based sort~~

so ~~$T(n) \in \Omega(n \lg n)$~~

~~$T(n) \in \Theta(n \lg n)$~~

$T(n) \in O(f(n))$

$\in O(n)$

WAYS TO PICK PIVOT

1. FIRST ELEMENT — COMMON CASE IS WORST
2. RANDOM (unif @ random) — WORST ONLY AT RANDOM
3. CLOSE TO MEAN
4. MEDIAN — CAN THIS BE DONE IN $O(n)$
5. MEDIAN-OF-THREE
6. TAKE A SAMPLE MEDIAN OF $k \ll n$ elts

REMEMBER

SUPER-LUCKY-SORT:

$O(n)$ b/c it discarded

$\frac{n}{c}$ elts at each round

Not QUITE ANALOGOUS

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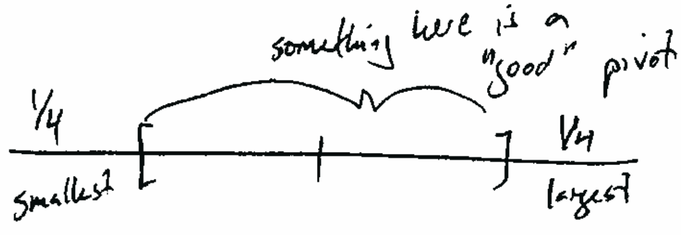
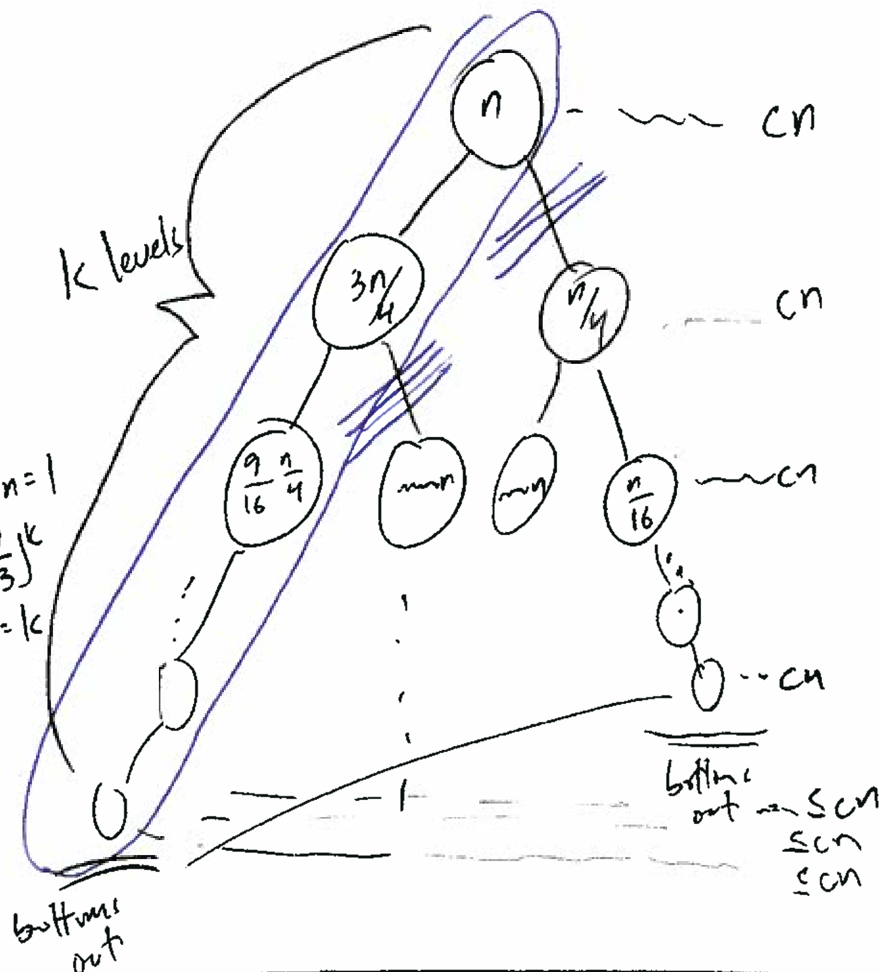


Odds of good pivot: 50%

$$T(n) \le T\left(\frac{n}{4}\right) + T\left(\frac{3n}{4}\right) + cn$$



$\left(\frac{3}{4}\right)^k n = 1$

$n = \left(\frac{4}{3}\right)^k$

$\log_{4/3} n = k$

$$\le cn \log_{4/3} n$$

$$\in O(n \lg n)$$

How many coin flips before heads? X = # of flips before heads

$$E[X] = \underbrace{\sum_{i=0}^{\infty} x \Pr[X=x]}_{\text{def'n}} = \sum_{i=1}^{\infty} i \Pr[X=i]$$

$$= 1 \cdot \frac{1}{2} + 2 \cdot \frac{1}{4} + 3\, \frac{1}{8} + \dots$$

3 $\quad 2E[X] = 1 + \frac{2}{2} + \frac{3}{4} + \frac{4}{8} + \dots$

$$2E[X] - E[X] = E[X] = 1 + 1/2 + 1/4 + 1/8 \dots = \frac{1}{1-\frac{1}{2}} = 2$$

Let X_i = time spent on recursion tree levels when largest A fragments are of size $n\left(\frac{3}{4}\right)^i \ldots n\left(\frac{3}{4}\right)^{i+1}$

$$E[\text{Sum over all } X_i] = E[X_0] + E[X_1] + \ldots + E[X_k]$$
$$\leq E[X_0] + E[X_1] + \ldots + E[X_{\log_{4/3} n}]$$

$E[X_i] = ?$

$n(3/4)^i$ Assume bad pivots do not help
pay cn for each bad pivot

⋮

$n(3/4)^{i+1}$ One good pivot completes this range and we pay cn.

$E[X_i] \leq \cancel{2cn}$ TOO MUCH $2cn\left(\frac{3}{4}\right)^i$

$E[\text{Sum of } X_i] \leq \sum_{i=0}^{\log_{4/3} n} 2cn\left(\frac{3}{4}\right)^i \cancel{(\log_{4/3} n + 1)2cn}$

$\in O(n \lg n)$

$$2cn \sum_{i=0}^{\log_{4/3} n} \left(\frac{3}{4}\right)^i$$
$$\leq 2cn \sum_{i=0}^{\infty} \left(\frac{3}{4}\right)^i$$
$$= 2cn \frac{1}{1-\frac{3}{4}}$$
$$= 2cn \frac{1}{1/4}$$
$$= 8cn$$

EXPECTED ~~PERFORMANCE~~ OF QUICK-SORT w/ RANDOM PIVOT is $\Theta(n \lg n)$

QUICK-MEDIAN: