Selection Sort

$O(n^2)$

Not stable
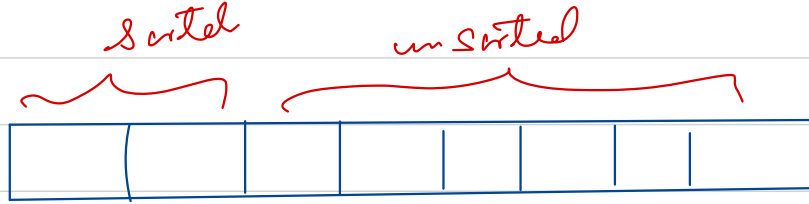
Sorted | unsorted

In any scenarios when we need to do min swaps to sort the data.

→ given a set of data, if we want to find the min element ⟶ Heap ⟹ Heap Sort

max heap

12	1	3	5	9	6	8	-2	4	33	0

$\underbrace{\qquad\qquad\qquad\qquad}_{\text{heap}}$

```
        0
       / \
      9   8
     /\   /\
    5  1 6  3
   /\
 -2  4
```
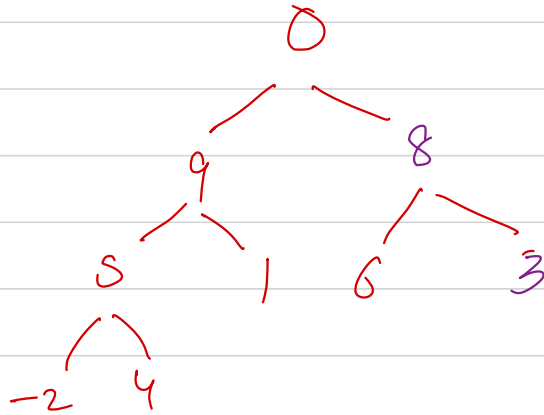
$0, 9, 8, 5, 1, 6, 3, -2, 4, 12, 33$

for each element → we do one pop. $O(\log n)$

$O(n \log n)$

Min heap

| 12 | 1 | 3 | S | 9 | 6 | 8 | -2 | 4 | 33 | 0 |

$-2, 0, 3, 4, 1, 6, 8, S, 12, 33, 9$

10^{-2}

reuse
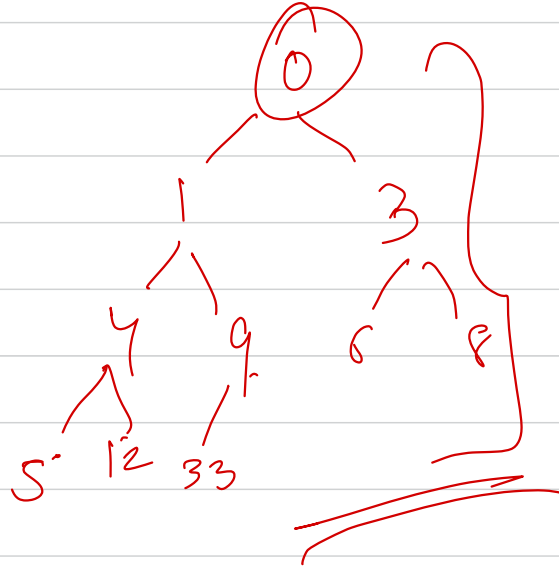
$O(n \log n)$

(x_1, y_1) (x_2, y_2)

$\longmapsto$ $|x_1 - x_2)$ $+ |y_1 - y_2)$

$x_1 \, y_1$ $x_2 \, y_2$

$x_3 y_3$

$\left.\begin{array}{c} 1 \\ 2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ 10 \end{array}\right\}$ $\longrightarrow$ $\left(+ \ x \ y\right)$ $\longrightarrow$ Store   then in   set $\underline{\underline{S}}$

$11 \longrightarrow$? $\underline{\underline{x \ y}}$

$$P_1 \to (X_1, Y_1) \qquad P_2 \to (X_2, Y_2)$$

Q. MOST DIST (codechef)

$$MD(P_1, P_2) = |x_1 - x_2| + |y_1 - y_2|$$

$$= \max(x_1 - x_2, x_2 - x_1) + \max(y_1 - y_2, y_2 - y_1)$$

$$= \max\left((x_1 + y_1) - (x_2 + y_2), (x_1 - y_1) - (x_2 - y_2), (-x_1 + y_1) - (-x_2 + y_2),\right.$$
$$\left.(-x_1 - y_1) - (-x_2 - y_2)\right)$$

$$f(x, y) = x + y$$
$$g(x, y) = x - y$$
$$h(x, y) = -x + y$$
$$m(x, y) = -x - y$$

$$= \max \left((x_1 + y_1) - (x_2 + y_2), (x_1 - y_1) - (x_2 - y_2), (-x_1 + y_1) - (-x_2 + y_2), \right.$$
$$\left. (-x_1 - y_1) - (-x_2 - y_2) \right)$$

$f(x,y) = x + y$

$g(x,y) = x - y$

$h(x,y) = -x + y$

$m(x,y) = -x - y$

Subtraction $= \underline{a - b}$

to maximize this subtracted value, a should be as high as possible

<u>Now</u> our third query asks $? X Y \rightarrow$ calc max md from all the points

$mD(P_i, P)$ $P_i \to x_i \; y_i$ $P \to x, y$ $\int \int \int \int$

$$= \max \left((x_i + y_i) - (x+y), (x_i - y_i) - (x-y), (-x_i + y_i) - (-x+y), \right.$$

$$\left. (-x_i - y_i) - (-x - y) \right)$$

$f(x, y) = x + y$

$g(x, y) = x - y$

$h(x, y) = -x + y$

$m(x, y) = -x - y$

for any query of type 3 P $x \; y$

$$\max \left(md(P_1, P), md(P_2, P), (P_3, P_4) - - - - - - \right)$$

$$\forall \; P_i \in S$$

$$= \max\Big((x_1+y_1)-(x+y),\ (x_1-y_1)-(x-y),\ (-x_1+y_1)-(-x+y),\ (-x_1-y_1)-(-x-y)$$

$$(x_2+y_2-(x+y)),\ (x_2-y_2)-(x-y),\ (-x_2-y_2)-(-x+y),\ (x_2-y_2-(-x-y))$$

t_2 :

r_3

|

$x_i^\circ - y_i^\circ - (x + y)$. — — .

$$= \max \Big((x_1 + y_1) - (x + y), \quad (x_2 + y_2) - (x + y) \quad \text{-----------} (x_n + y_n) - (x + y),$$

$$(x_1 - y_1) - (x - y), \quad (x_2 - y_2) - (x - y), \qquad \text{--------} (x_n - y_n) - (x - y),$$

$$(-x_1 + y_1) - (-x + y), \quad (-x_2 + y_2) - (x - y) \quad \text{-------} (-x_n - y_n) - (-x + y)$$

$$(-x_1 - y_1) - (-x - y), \quad (-x_2 - y_2) - (-x - y) \text{----} (-x_n - y_n) - (-x - y)$$

$$\Big)$$

$$= \underline{\max} \Big(\max (f(P_1, P)), \quad \max (g(P_1, P)), \quad \max (h(P_1, P)),$$

$$\max (m(P_r, P)) \Big)$$

$$\forall \ P_i \in S$$

4 heaps

$$h_1 \longrightarrow \max \ (x_i + y_i) \longrightarrow O(1)$$

$$h_2 \longrightarrow \max \ (x_i - y_i) \longrightarrow O(1)$$

$$h_3 \longrightarrow \max \ (-x_i + y_i) \longrightarrow O(1)$$

$$h_4 \longrightarrow \max \ (-x_i - y_i) \longrightarrow \underline{O(c)}$$

$$2 \ \underline{x, y} \longrightarrow \underline{O(\log n)}$$

$$+ x, y \longrightarrow O(\log n)$$

$$- x, y \longrightarrow O(1) \longrightarrow \text{visited array (map)}$$

$$\left(\begin{array}{c} 1 \longrightarrow \text{push} \\ 1 \longrightarrow \text{pop} \end{array} \right)$$

$$\overset{n}{\underline{\underline{n (q, y)}}}$$

K largest elements

Kth most fre ele
↳ return root

Q→ Given an array, find the K most frequent elements.

2, 4, 1, 4, 9, 1, 3

$K = 2$

(2-1)
(4-2)
(1-2) ←
(9-1) ←
(3-1)

{1, 4}

$n \leq 10^6$

min heap → K

| 1~2, 4~2

Given an array, find the K smallest elements.

$$1, -1, \quad 3, -7, \quad 6 \qquad K = 3$$

$$\{-7, -1, 1\}$$

$O(n \log K)$

$O(K)$

every term i maintain a
set of K elements

$\rightarrow$ How to replace,

remove then add

$\boxed{1, -1, -7}$

K size heap (max)

max elemt $\rightarrow$ heap

K^{th} smallest elemt