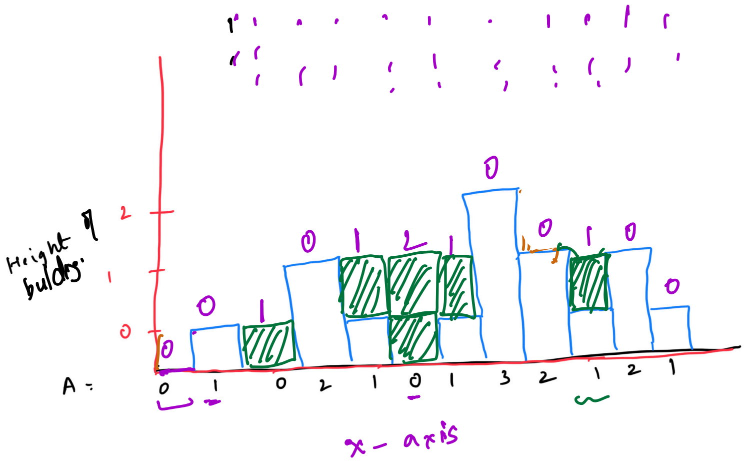
Question: Rain water Trapping

→ Given heights of N buildings

→ Compute the amount of water that will be trapped

A : 0 1 0 2 1 0 1 3 2 1 2 1

width of building = 1 unit



Ans = 6

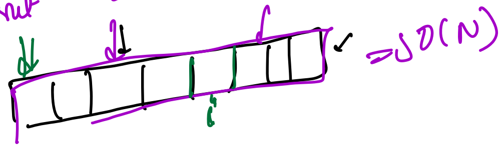
W_i = Amount of water stored above building i

Ans = $\sum W_i$

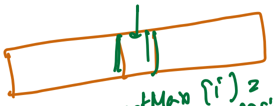
{

Contribution

construct rightMax => O(N)

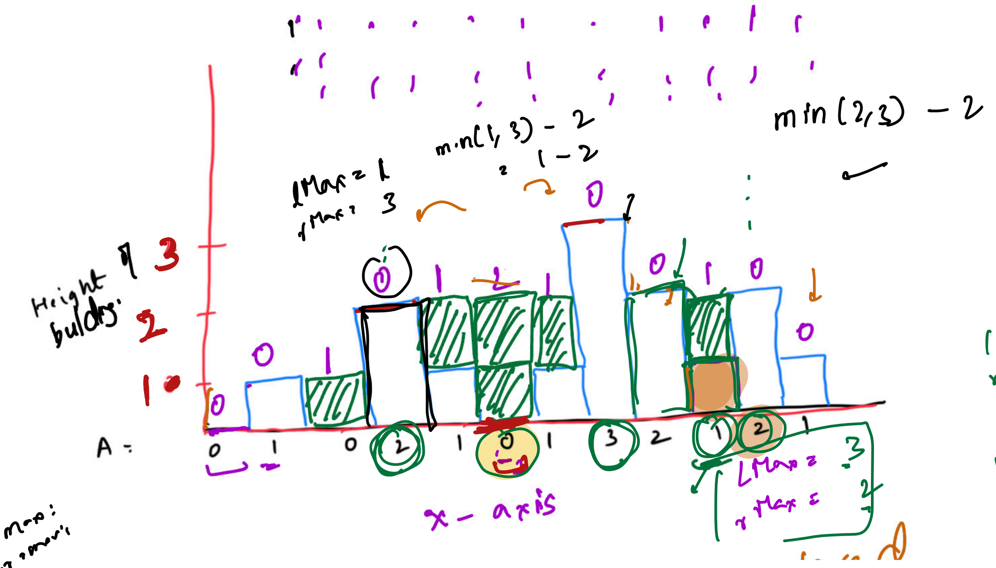


W_i



rightMax[i] = max(A[i.....N-1])

max =



currMax:
currMax =

lMax = 3
rMax = 2

lMax = 3
rMax = 2
min(

min(3,2) = 2

leftMax = 2 ✓
rightMax = 3 ✓

min(leftMax, rightMax) units of water

$W_i = \min(LeftMax, rightMax) - h_i$

Brute force :

Simply iterate and get lMax & rMax

lMax = max(0..... i)

rMax = max(i.... n-1)

```
for(i=0; i<N; i++){
O(N) <- // Find l Max
O(N) <- // Find rMax
}
```

T.C : $O(N^2)$

S.C : $O(1)$

Efficient Approach

for every 'i', we need leftMax [i] and rightMax [i]

T.C: O(N) + O(N) + O(N) => O(N)

↓ leftMax ↓ rightMax ↓ finding ans

S.C: O(N) => 2extra array

```
ans =0;
for ( i = 0;  i<N;  i++) {
    ans += min ( LeftMax [i], rightMax [i] ) - height[i]
}
```

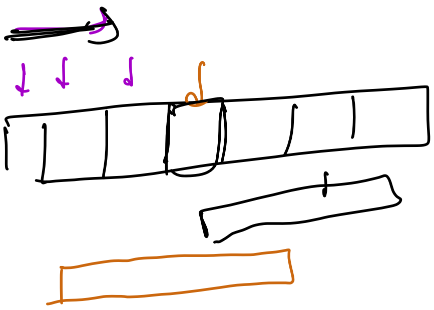
T.C: O(N)
S.C: O(N)

✓ Approach3:

Carry forward $\boxed{\text{leftMax}}$ as a single variable

T.C: O(N) + O(N)
S.C: O(N)
↓
$\boxed{\text{1extra array}}$

$\boxed{\text{leftMax = 0}}$



Question: First missing non-negative Integer

Given an unsorted array, find the smallest non-negative number missing from the array

A = 8 10 1 -3 2 -5 0

0 ✓
1 ✓
2 ✓
3 X

Ans = 3

Quiz: [1, 2, 5, 6, 4, 3]

0 ✓

Ans = 0

Quiz: 2 4 -1 -6 3 7 8 4 -3 0

0 ✓
1 X

Ans = 1

Quiz: { 3 1 5 0 2 4 }

Ans = 6

Brute Force :

Check for 0, 1, 2, 3 . . . . —

min = 0

max = N

If 0 is not answer => 0 should be present

1 " " " => 1 " " "

2 " " " => 2 " " "

3 " " " => 3 " " "

N-1 is not answer => N-1 should be present

Array Size : $\boxed{N}$

[0, 1, 2 . . . . . N-1]

N is the first missing non-negative int

A = -3 -4 -5 -6

Ans = 0

A = 0 1 3 5 6 $\boxed{10^9}$ = Safer upper bound

$\boxed{2}$

Ans = 10^9+1

-1 0 1 2 3 4 5

N = 7

N = 6

[0, 7]

```
for(i=0; i<=N; i++){
O(N) ← // check if i exists in array
}
```

T.C : $O(N^2)$

S.C : $O(1)$

Approach2 : Hashset.

=> Insert all elements into set. => O(N)

```
for(i=0; i<=N; i++){
O(1) ← // check if i exists in array }
O(N)
}
```

T.C : O(N) + O(N) = O(N)

S.C : O(N)
↓
Hashset

Approach3 : Sort the array

A = -5 -3 0 1 2 8 10

=>

x = ~~0~~ ~~1~~ ~~2~~ 3

Ans = 3

T.C: $O(N\log N) + O(N) = O(N\log N)$

S.C: $O(1)$

A = 0 1 2 3 4 5

min1 = 0

min2 = 1

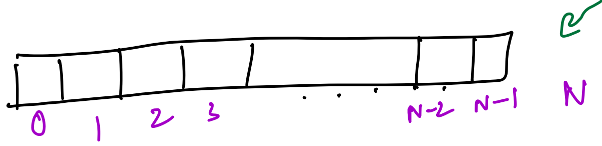
$A = [-2, 0, 1, \underbrace{10000, 20000]}$

Efficient Approach

Hashset ? $\underbrace{0, 1, 2, 3 \dots\dots N}$

$\boxed{[0 - N]}$

A =



N = 7

Ans = [0, 7]

$\boxed{5}$

Indices Range : [0, N-1]

Lets consider only elements in the range [0, N-1]

A =	0	1	2	8	10	-5	6
	0	1	2	3	4	5	6

[0,N-1] => [0, 6]

N = 7

ans: [0, N]

N = 4

A =	0	1	6	1
	0	1	2	3

[0 - 3]

$\boxed{\text{Swap only if they are not equal}}$

A =	0	1	2	3	4
	0	1	2	3	4

T.C: O(N)

S.C: O(1)

$\boxed{\text{7mins?}}$

A =	0	1	2	3
	0	1	2	3

2) O(N)

$\boxed{\text{long}}$

$[-2\times10^9, 2\times10^9]$

↓

N:

$[-\infty, \infty]$

Question: Max absolute difference ✓

Given an array of N integers, find the maximum value of the

$$\boxed{F(i,j)} = |arr[i] - arr[j]| + |i - j|$$

$0 \le i, j \; N-1$

$[arr[i] - arr[j] + i - j]$

Ex1: A:

$$\begin{array}{ccc} & i & j \\ & \downarrow & \downarrow \\ 1 & 3 & -1 \\ 0 & ① & ② \end{array}$$

$\boxed{i = 1 \quad j = 2}$

A[i], A[j]

$F(i,j) = |3 - (-1)| + |1 - 2|$

$4 + 1 = \boxed{5}$

Ex2: $A = $

$$\begin{array}{cccc} 1 & 2 & 3 & 1 \\ 0 & 1 & 2 & 3 \end{array}$$

$i = 0 \quad j = 2$

$|1 - 3| + |0 - 2|$

$2 + 2 = \boxed{4}$

Ex3:

$$\begin{array}{ccccc} 1 & 5 & 2 & 2 & 4 \\ 0 & 1 & 2 & 3 & 4 \end{array}$$

$|1 - 4| + |0 - 4| = \boxed{7}$

$i = 0, \; j = 4$

max = 5

min = 1

$|5 - 1| + |1 - 0| = \boxed{5}$

$|A[i] - A[j]| = |A[j] - A[i]|$

Brute Force

$A : [\underset{0}{1}, \underset{1}{3}, \underset{2}{-1}]$ $N=3$

Consider all the pairs

$F(i,j) = |A[i] - A[j]| + |i - j|$

i	j	$F(i,j)$
0	0	$\Rightarrow$ 0
0	1	$\Rightarrow \ |1-3| + |0-1| = 3$
0	2	$\Rightarrow \ |1-(-1)| + |0-2| = 4$
1	0	$\Rightarrow \ |3-1| + |1-0| = 3$
1	1	$\Rightarrow \ 0 + 0 = 0$
1	2	$\Rightarrow \ |3-(-1)| + |1-2| = 5$
2	0	$\Rightarrow \ |-1-1| + |2-0| = 4$
2	1	$\Rightarrow \ |-1-3| + |2-1| = 5$
2	2	$\Rightarrow \ 0 + 0 = 0$

Observations :

1) $F(i,i) = 0$

2) $F(i,j) = F(j,i)$

Consider $\boxed{i < j}$

```
for(i=0; i<N; i++){
    for(j= i+1 ; j<N; j++){
        ans = max( ans, F(i,j) )
    }
}
```

T.C : $O(N^2)$

S.C : $O(1)$

Solution :

$$|x| \begin{cases} x & \text{if } x \geq 0 \\ -x & \text{if } x < 0 \end{cases}$$

$x = -2$

$|x| = -x$ $(-(-2) = 2$

$x = 2$

$|x| = x$

$F(i,j) = |A[i] - A[j]| + |i - j|$ $\{ i < j \}$

$-x = i - j < 0$

$|x| = -x$

$|i - j| = -(i-j) = -i + j$

$F(i,j) = |A[i] - A[j]| + j - i$

if($A[i] > A[j]$)

Case 1: $A[i] \leq A[j]$ }

only if $A[i] \geq A$

$F(i,j) = (A[j] - A[i]) + (j - i)$

$F(i,j) = (A[j] + j) - (A[i] + i)$

$max1 = \forall_{i,j} \max F(i,j)$ }

2)

$A = $ 3 1 -2 4

0 1 2 3

$i = 1, \; j = 2$

Case 2: $A[i] > A[j]$

$F(i,j) = A[i] - A[j] + j - i$

$F(i,j) = (A[i] - i) - (A[j] - j)$

$max2 = \forall_{i,j} \max(F(i,j))$

ans = max (max1, max2)

Case 1:

$$F(i,j) = (A[j] + j) - (A[i] + i)$$

$$\max 1 = \forall_{i,j} \max F(i,j)$$

$$X[k] = A[k] + K$$

$$F(i,j) = (\underbrace{X[j]}_{\max} - \underbrace{X[i]}_{\min})$$

$$\max 1 = \forall_{i,j} \max (\underbrace{X[j]}_{\max} - \underbrace{X[i]}_{\min})$$

✓

$$\begin{array}{cccc} & 0 & 1 & 2 \\ A = & 1 & 3 & -1 \\ X = & 1 & 4 & 1 \end{array}$$

$O(N)$

$$\max 1 = (4 - 1) = \boxed{3}$$

max = 4
min = 1

Case 2:

$A[i] > A[j]$

$F(i,j) = A[i] - A[j] + j - i$

$F(i,j) = (A[i] - i) - (A[j] - j)$

$\text{max2} = \underset{i,j}{\forall} \max(f(i,j))$

$Y[k] = A[k] - k$ ✓

$F(i,j) = Y[i] - Y[j]$

$\text{max2} = \underset{i,j}{\forall} \max(\underset{\text{max}}{\underset{\downarrow}{Y[i]}} - \underset{\text{Min}}{\underset{\downarrow}{Y[j]}})$

$A = \begin{array}{ccc} 1 & 3 & -1 \\ 0 & 1 & 2 \end{array}$

$Y = \begin{array}{ccc} 1 & 2 & -3 \end{array}$

max = 2

min = -3

$\text{max2} = \text{max} - \text{min}$

$= 2 - (-3)$

$= \boxed{5}$

$\text{ans} = \max(\text{max1}, \text{max2})$

$= \max(3, 5)$

ans = 5

Steps

O(N) 1)) Construct array X

O(N) 2) Find max & min of X

O(1) 3) max1 = X_max − Xmin

O(N) 4) Construct array Y

O(N) 5) find Y_max, Ymin

O(1) 6) max2 = Ymax − Ymin

O(1) 7) ans = max(max1, max2)

T.C: O(N)

S.C:

```
Xmax = -INF,        Xmin = +INF
Y_max = -INF,       Y_min = +INF

for(i=0;  i< N;  i++){
    X_max =   max( X_max,  A[i] + i  )
    X_min =   min( X_min,  A[i] +i)
    Y_max =   max (Y_max,  A[i] - i  )
    Y_min =   min ( Y_min,  A[i] i   )
}
return  max (X_max− Ymin , Y_max − Ymin)
```

T.C: O(N)

S.C: O(1)

Doubts

If $A[j] > A[i]$

Case 1: $\boxed{A[i] \leq A[j]}$

$F(i,j) = A[j] - A[i] + j - i$

$F(i,j) = (A[j] + j) - (A[i] + i)$

2) $A[j] > A[i]$

max| = $\forall_{i,j} \max F(i,j)$

$X[k] = A[k] + k$

$F(i,j) = X[j] - X[i]$

$\boxed{i < j}$

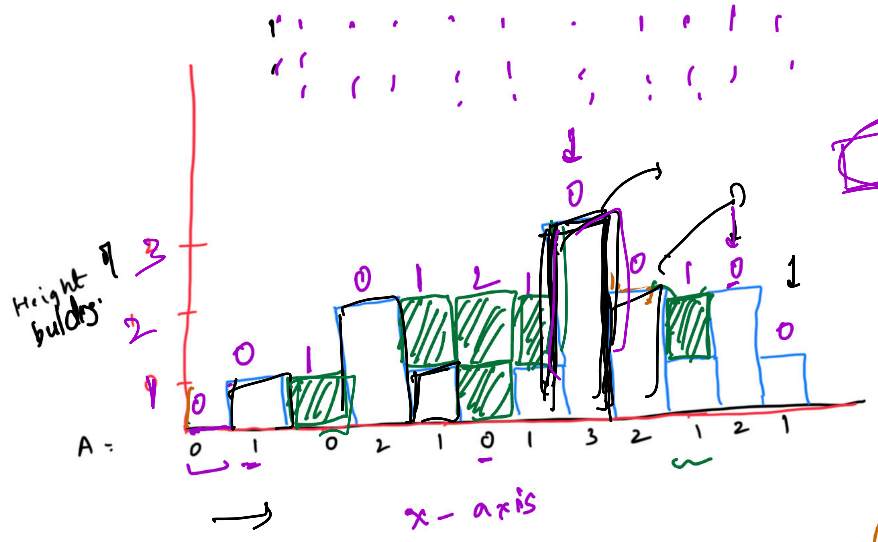
$\max(X, Y)$

$\boxed{Y > X}$

$\boxed{A[i] > A[j]}$

max = ~~1~~ ~~2~~ 3

temp = ~~2~~ 1



$\boxed{max < 2max - 2}$

2m - 3 2)

2m 7

(2^m -

2m - m = temp

temp = m

$\overset{2}{(a\ b)}$