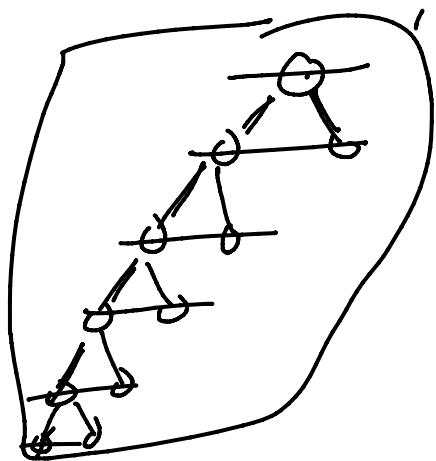


$$2^0 + 2^1 + 2^2 + 2^3 + \dots + 2^{n-1} = n$$



$$\frac{n}{2} \Rightarrow r$$

= Priority Queue

Implement using

$$2^n = n+1$$

$$h = \log_2 n$$

$$O(n)$$

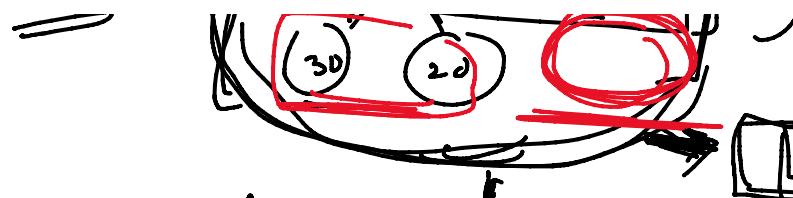
Binary Heaps

Min
Max

Min Heap
Max Heap



Node



Representation of Heaps

Convert to 1D Array

Flatten of Tree



$$\frac{2 \times i + 1}{2} = f$$

Parent, child

$$2 \times i + 2$$

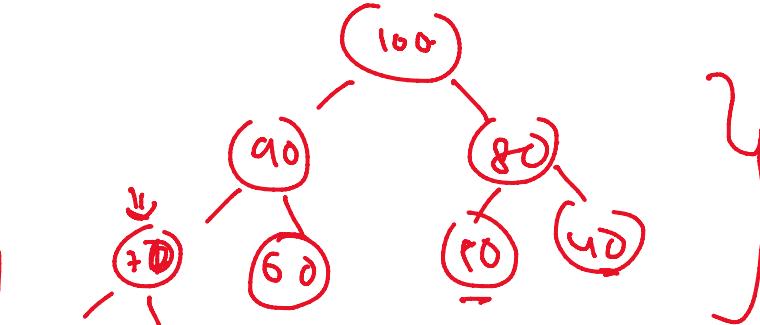
i_{dn} → Parent Node = $\left(\frac{i_{dn}-1}{2}\right)$

$$i_{dn} = 2 \cdot i_{lc} + 1 \\ i_{ch} = \left\lfloor \frac{i_{lc}-1}{2} \right\rfloor$$

$$\text{left child} = 2 \cdot i_{dn} + 1;$$

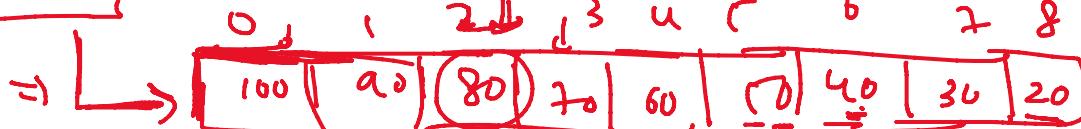
$$\text{Right child} = 2 \cdot i_{dn} + 2$$

Insertion
Deletion
Get



$$\text{left} \\ = 2 \cdot 2 + 1 = 5$$

$$2 \cdot 2 + 2 = 6$$



Array
(Pa)

$\frac{i_{dn}-1}{2} = \frac{5}{2} = 2$
 $\frac{8-1}{2} = \frac{7}{2} = 3$

child Parent

Binary Heap
why complete?
Heap to Array
child ~ Parent

Complexity

Heap → Array
child ~ Parent

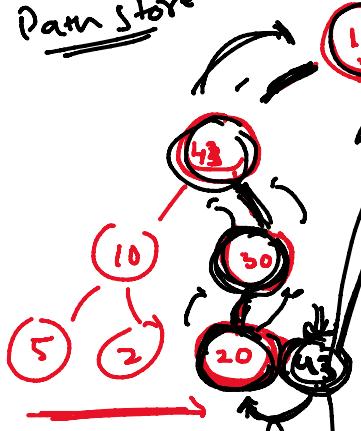
Heap → Structure?

insertion
deletion
get

Complex

Insertion in Heap

Data Store



100

43

40

10

30

35

38

15

2

20

45

→ 43

MaxHeap¹ = 1

Step 1 → calculate Node

Step 2 → update priority

level by level → upPriority

$T.C \approx O(\log_2 n) \Rightarrow O(H)$

UPPriority operation

40

30

35

38

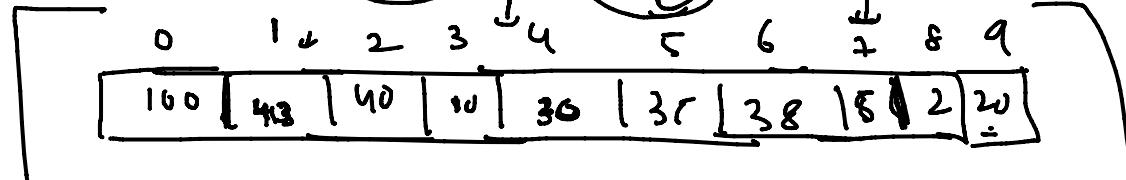
15

2

20

45

43



$\frac{1-1}{2} = 0$

$\frac{4-1}{2} = 1$

$\frac{9-1}{2} = 4$

qdn →

$\left(\frac{\log_2 - 1}{2} \right)$

Deletion in Binary Heap

p@

qet

DownPriority

40

20

10

5

2

4

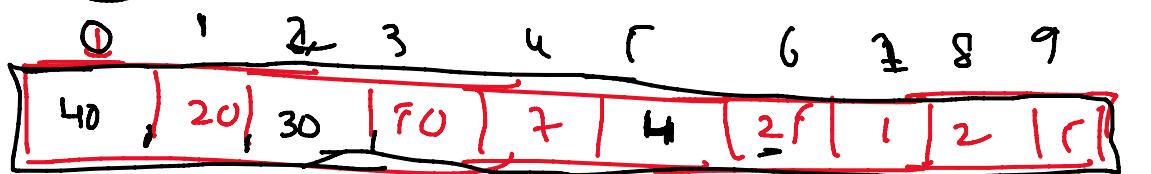
25

HeapX

T.C: $O(n+1) = O(\log_2 n)$

Max Heap

II



$$\begin{aligned}2 &= 0 + 1 \\2 &= 0 + 2\end{aligned}$$

$$\begin{aligned}2 &= 2 + 1 \\2 &= 2 + 2\end{aligned} = 5$$

$$\begin{aligned}2 &+ 1 + 1 = 1 \\2 &+ 1 + 2 = 3\end{aligned}$$

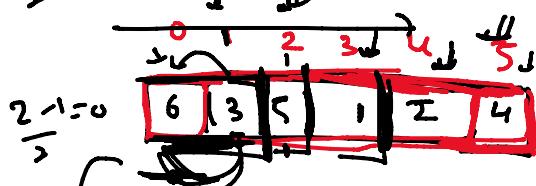
Pop-back

Insertion, Deletion

Build a Binary Heap?

$$\begin{aligned}\frac{1-1}{2} &= 0 \\ \frac{2-1}{2} &= 1\end{aligned}$$

10 insertion, upHeapify



ith element heap
(0 - i-1)

$$\frac{2-1}{2} = 0$$

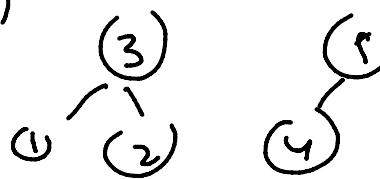
$$\frac{1-1}{2} = 0$$

$$\frac{3-1}{2} = 1 \quad \frac{5-1}{2} = 2$$

$$\frac{7-1}{2} = 3$$

Build Heap using upHeapify

Main Heap

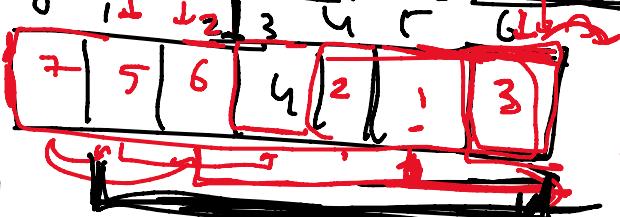


Build Heap Using DownHeapify?

lcl

$$\begin{aligned}2 &= 1 + 1 \\&= 3\end{aligned}$$

X



$$2 = 2 + 1 = 3$$



