

9) $O(n^2)$ $O(n^2)$ $O(n^2)$

3) $O(n^2)$ $O(n^2)$ $O(n^2)$

1) $O(n^2)$ $O(n^2)$ $O(n^2)$

5) $O(n^2)$ $O(n^2)$

1) $O(n^2)$ $O(n^2)$ $O(n^2)$

1) $O(n^2)$ $O(n^2)$ $O(n^2)$

1) $O(n^2)$ $O(n^2)$ $O(n^2)$

$O(n)$ $O(\log n)$ $O(n)$ $O(n)$

$O(n)$ $O(n)$ $O(n \log n)$ $O(n)$ $O(n)$

$O(k \log n)$ $O(n + k \log n)$ $O(n \log n)$ $O(\log n)$ $O(n)$

$O(k \log k)$

$O(n)$ $O(n)$ $O(n)$

Dijkstra

to shortest

paths

~~tree~~
graph

Insert(x, Q)

$h = |V|$

min(Q)

h

del min(Q)

h

Decrease key(x, Q, Δ)

$m = |E| \leq h^2 - h$

↓
is wrong

Delete
+ insert

find $|V| \rightarrow$ ~~cost~~ delete

cost

cost \rightarrow $|V| \rightarrow$ cost

tree $h \log h + m \cdot h$

also cost \rightarrow $|V| \rightarrow$ cost \rightarrow $|V| \rightarrow$ cost

cost \rightarrow $|V| \rightarrow$ cost \rightarrow $|V| \rightarrow$ cost

decrease key \rightarrow $|V| \rightarrow$ cost

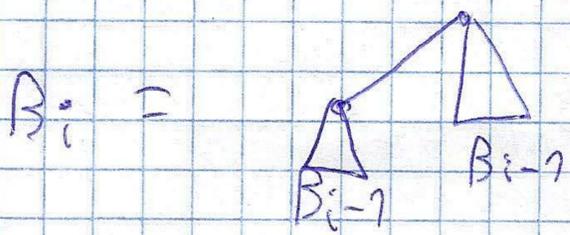
node \rightarrow $|V| \rightarrow$ cost

cost \rightarrow $|V| \rightarrow$ cost \rightarrow $|V| \rightarrow$ cost

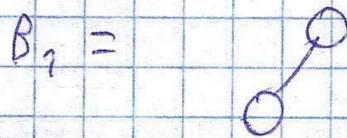
$O(h \log h + m \cdot \log h)$

$m = O(h^2)$ \rightarrow $m \log h$ \rightarrow $|V| \rightarrow$ cost

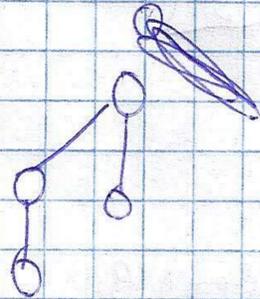
מסלול נורמלי



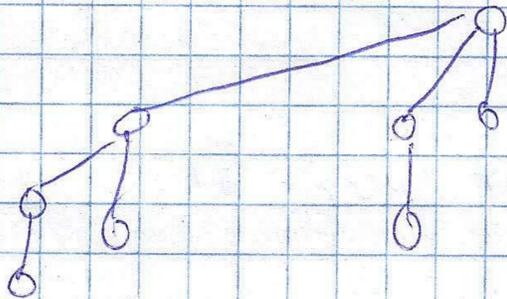
$B_0 = 0$



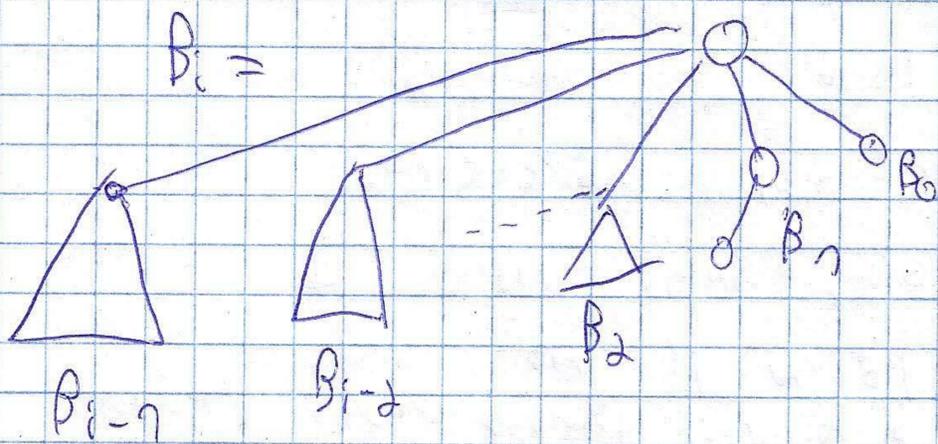
$B_2 =$



מסלול נורמלי
 מסלול נורמלי
 מסלול נורמלי



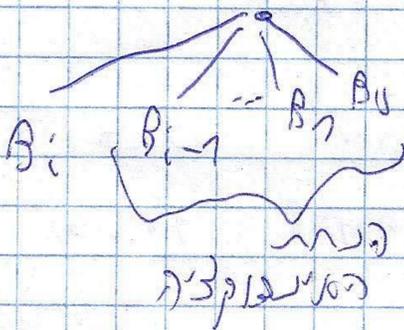
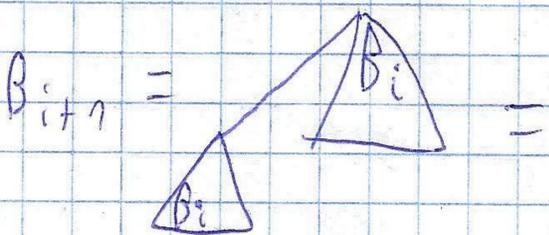
מסלול



מסלול נורמלי

$B_i =$ מסלול נורמלי

SLC



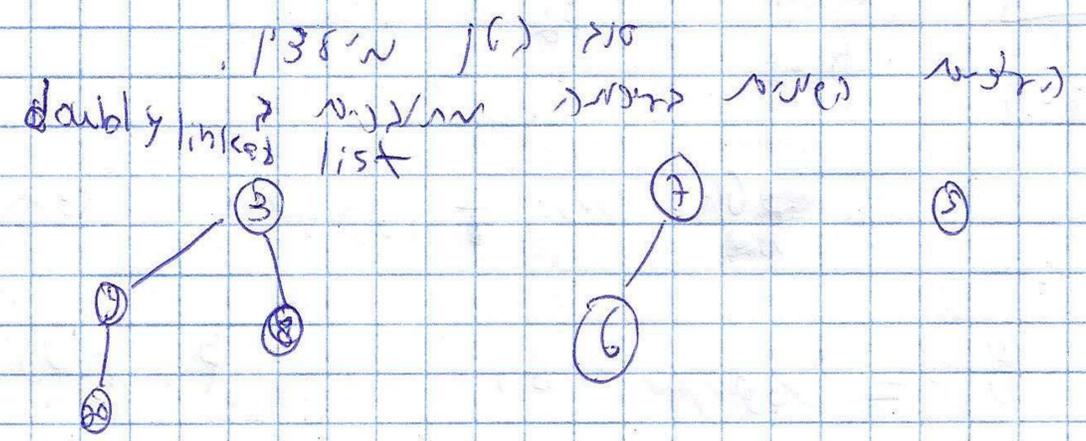
$\log_2 n$ $\log_2 n$ $\log_2 n$ $\log_2 n$ $\log_2 n$ $\log_2 n$

$|B_{k+1}| = 2|B_k|$ $|B_{1c}| = 2^{1c}$

$depth(B_{1c}) = 1c$

$depth(B_{1c+1}) = depth(B_{1c}) + 1$

new level, new nodes, new edges, new weight



new level, new nodes, new edges, new weight

new level, new nodes, new edges, new weight

new level, new nodes, new edges, new weight

Number of nodes decreases as leaf (x, y, A)

Number of nodes decreases as leaf (x, y, A)
 $\log(h)$

~~Amortized~~

$O(h \log h)$ amortized cost

Number of nodes decreases as leaf (x, y, A)

0 0 0
0 0 1
0 1 0
0 1 1
1 0 0
1 0 1
⋮

Number of nodes decreases as leaf (x, y, A)
 $O(h)$ amortized cost

Increment of amortized cost

Number of nodes decreases as leaf (x, y, A)

Amortized cost

Number of nodes decreases as leaf (x, y, A)

Number of nodes decreases as leaf (x, y, A)

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Number of nodes decreases as leaf (x, y, A)

Amortized $O(1)$

Number of nodes decreases as leaf (x, y, A)

Number of nodes decreases as leaf (x, y, A)

Number of nodes decreases as leaf (x, y, A)

Lazy Mails

do follow and for new
 - with some of the minimum cost

map of nodes delete min for 50

del-min map of nodes
 : 30 20 10 5

map of nodes delete min for 50

del-min map of nodes

map of nodes delete min for 50

del-min map of nodes

map of nodes delete min for 50

map of nodes

del-min map of nodes

map of nodes delete min for 50

del-min map of nodes

$$\text{Amortized} = (\# \text{ links} + \text{max rank}) - (\# \text{ links} - \text{max rank})$$

link of server

Array setup

every link removes tree

del-min map of nodes

leaf node

Find min $O(1)$ w.c.

Merge - $O(1)$ w.c.

Insert - $O(1)$ w.c.

leaf node

Leaf Merge

Amortized $O(1)$ w.c.
 $O(1) = \frac{1}{n}$
 $O(1) = \frac{1}{n}$

delete min Amortized $O(\log)$

Amortized $O(\log)$

Decrease key $O(\log)$ w.c.

Amortized $O(1)$

Amortized $O(1)$ w.c.

Decrease key $O(\log)$

Amortized $O(1)$ w.c.

Amortized $O(1)$ w.c.

Amortized $O(1)$ w.c.

~~Amortized $O(1)$ w.c.~~

Amortized $O(1)$ w.c.

Amortized $O(1)$ w.c.

Amortized $O(1)$ w.c.

$\log h$
 Rank of the tree = degree of the root

Rank of the tree = degree of the root

Successive linking - Delete min

Insert

Cascading cuts for decrease key

Node

Node

Node

Node

Node

Node

Node

$\log h$

$O(1)$

decrease min

decrease min

decrease key

$O(\log h)$

Cascading cuts delete

for non sorted array

work with 2 pointers - min, max

decrease key

no swap

is it possible to find min, max

min, max

decrease key

is it possible to find min, max

Insert

decrease key

is it possible to find min, max

log