

The background of the slide is white, decorated with several large, overlapping circles in four colors: red, teal, lime green, and dark grey. A central white rectangular box with a lime green border contains the text.

CS 30A: Discussion

Week 3: Hashing and Heaps

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Outlines:

1. Hashing

- Probing and clustering

2. Heaps

- Bottom-up Construction

3. Algorithm Design

- Two Sum

Hashing: Probing and clustering

elements: [89, 18, 49, 20, 11, 12, 30, 43] hash function: $f(x) = x \bmod 10$

Linear Probing

49	20	11	12	30	43			18	89
0	1	2	3	4	5	6	7	8	9

Primary
Clustering

Separate Chaining

20	11	12	43					18	89
0	1	2	3	4	5	6	7	8	9

[5, 1, 2, 8, 7, 3, 4, 6, 9, 10] $f(x)+5 \rightarrow f(x)+1 \rightarrow f(x)+2$

Random Probing

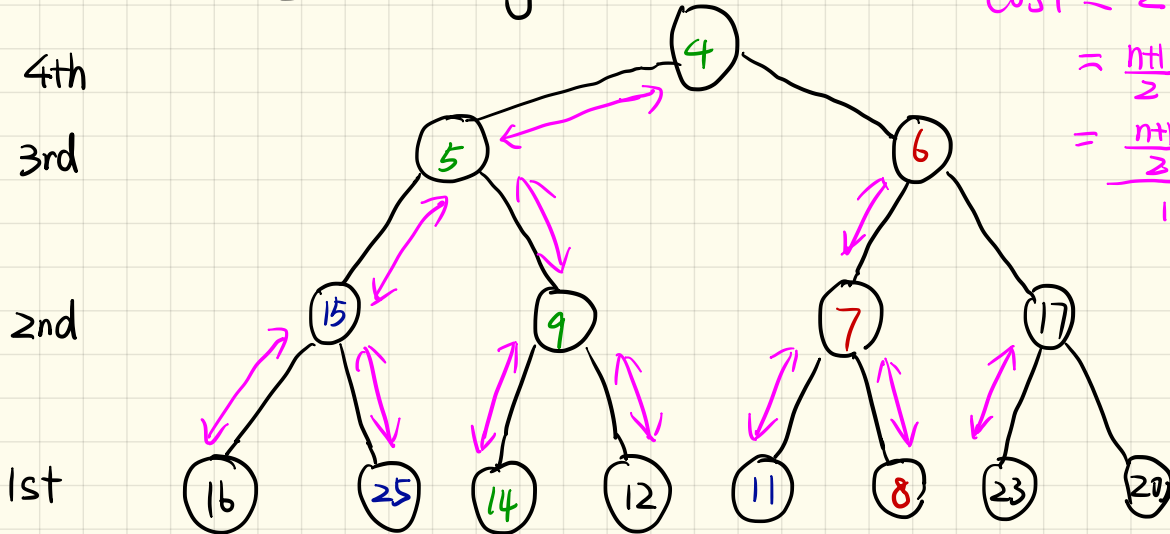
20	11	12	43	49	30			18	89
0	1	2	3	4	5	6	7	8	9

Heaps: Bottom-up Construction

Heap: Binary tree where parent nodes are smaller than their children.

Elements: [16, 15, 4, 12, 6, 7, 23, 20, 25, 9, 11, 17, 5, 8, 14]

Insert one by one: $O(n \log n) \implies O(n)$



$$\begin{aligned} \text{cost} &\leq \sum \text{edges} \\ &= \frac{n+1}{2} + \frac{n+1}{4} + \dots + 2 \\ &= \frac{n+1}{2} \div 1 \\ &\quad \frac{1 - \frac{1}{2}}{1 - \frac{1}{2}} = n - 2 \\ &= O(n) \end{aligned}$$
$$\frac{n+1}{4}$$
$$\frac{n+1}{2}$$

Algorithm Design : Two Sum

Given an array A , a target value s , find two numbers in A that add up to s .

① Brute Force Algorithm: $O(n^2)$

for all pairs $(A[i], A[j])$ $O(n^2)$
return $A[i], A[j]$ if $A[i] + A[j] = s$ $O(1)$

$A = [3, 2, 7, 5, 11, 16], s = 9$

$3 \rightarrow$ find 6 ; $2 \rightarrow$ find 7

For $A[i]$, find $s - A[i]$

② Sorting and Binary Search $O(n \log n)$

sort A $O(n \log n)$
for all $A[i]$: $O(n)$
binary search for $s - A[i]$ $O(\log n)$
return if found

$A' = [2, 3, 5, 7, 11, 16], s = 9$

Cost of finding:

Binary search: $O(\log n)$

Hashing: $O(1)$

③ Hashing $O(n)$

for all $A[i]$: $O(n)$
put $A[i]$ in a hash table $O(1)$
for all $A[i]$ $O(n)$
find $s - A[i]$ in the hash table $O(1)$
return if found