TWO POINTER TECHNIQUE

lecture (1)

Two Sum / Target Sum Pairs

- → Unsorted
- → Sorted
- → Count
- → Count Unique
- → Two Matrices

→ Design

- → Closest
- → Absolute
- → Smaller
- → Greater

Difference Pairs

→ Target Diff Pairs

- → All
- → Unique

→ Longest Diff Pair (I & II)

3 Sum

Target Sum Triplets

→ Unique

→ Smaller

→ Closest

Count Valid Triplets

Valid Triangles

Max Sum Triplet

Minimize Differences

lecture (2)

4 Sum

→ 4 Sum (I & II)

→ Count Tuples

→ Sum

→ Product

K Sum

Q) Two Sum - Unsorted

target => 10

7	2	4	9	4	5	2	5
0	1	2	3	4	5	6	7

Hashmap

7→0
2→1
4→2,4
9→3
5→5
2→6

→ O(N) extra space

O(N) Time

Single Traversal

→ $O(N^2)$
Brute force

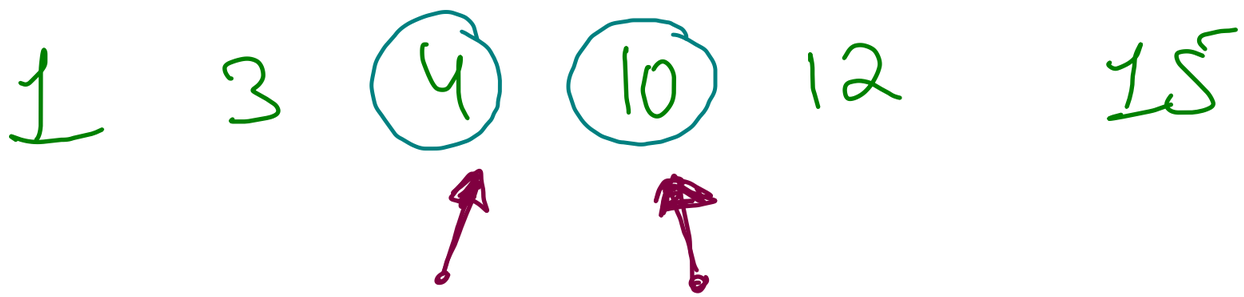
→ O(N)T, O(N)S
Hashmap

→ O(NlogN)T
O(1)S
Two Pointer

```
public int[] twoSum(int[] nums, int target) {
    HashMap<Integer, Integer> comp = new HashMap<>();

    for(int i=0; i<nums.length; i++){
        if(comp.containsKey(target - nums[i]) == true){
            return new int[]{comp.get(target - nums[i]), i};
        }
        comp.put(nums[i], i);
    }

    return null;
}
```

O(1/2) Two Sum → Sorted

target = 14



O(n) time

O(1) extra space

|+|5| > 14

↑|+12 < 14

3+12↓ > 14

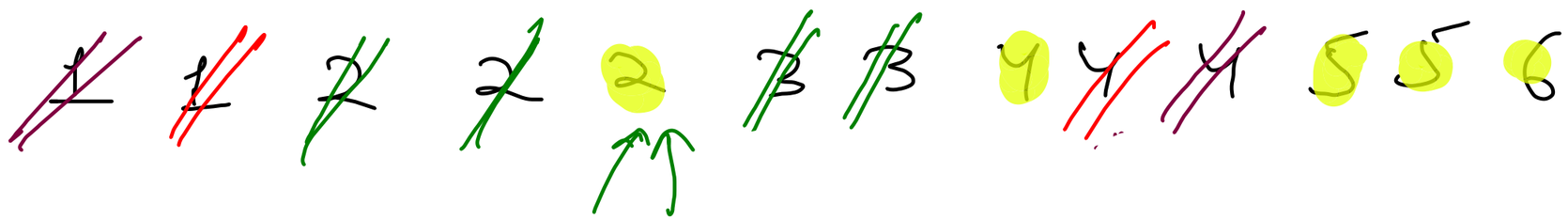
↑3+10 < 14

```
int left = 0, right = nums.length - 1;
while(left < right){
    int sum = nums[left] + nums[right];
    if(sum == target){
        return new int[]{left + 1, right + 1};
    } else if(sum > target){
        right--;
    } else {
        left++;
    }
}

return null;
```

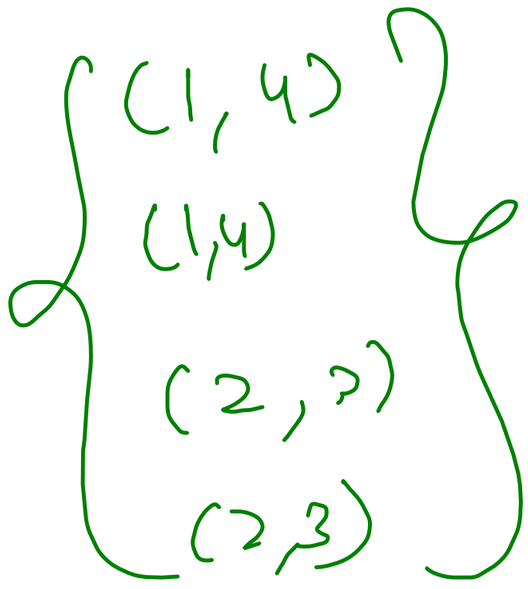
Q(1679)

Target Sum Pairs → Remove

target = 5



Count of pairs = 0 1 2 3 4



O(NlogN) Time

O(1) Extra space

```java
public int maxOperations(int[] nums, int target) {
    Arrays.sort(nums); ← NlogN
    int left = 0, right = nums.length - 1;
    int count = 0;
    while(left < right){
        int sum = nums[left] + nums[right];
        if(sum == target){
            count++;
            left++; right--;
        } else if(sum > target){
            right--;
        } else {
            left++;
        }
    }

    return count;
}
```

O(N)

Lint code

(387) Unique Target Sum Pairs

target = 5

1 1 2 2 2 3 3 4 4 4 5

```
public int twoSum6(int[] nums, int target) {
    Arrays.sort(nums);
    int left = 0, right = nums.length - 1;
    int count = 0;
    while(left < right){
        if(left > 0 && nums[left - 1] == nums[left]){
            left++; continue;
        }

        int sum = nums[left] + nums[right];
        if(sum == target){
            count++;
            left++; right--;
        } else if(sum > target){
            right--;
        } else {
            left++;
        }
    }

    return count;
}
```

{1,4}

{2,3}

unique = 2

Two Sum - Closest

Lintcode 533


```java
public int twoSumClosest(int[] nums, int target) {
    Arrays.sort(nums);
    int left = 0, right = nums.length - 1;
    int abs = Integer.MAX_VALUE;
    while(left < right){
        int sum = nums[left] + nums[right];
        if(sum == target){
            return 0;
        } else if(sum > target){
            abs = Math.min(abs, sum - target);
            right--;
        } else {
            abs = Math.min(abs, target - sum);
            left++;
        }
    }

    return abs;
}
```

O(NlogN)

O(N)

target = 14

ans = ~~16~~ 18 11

1+16 = |17-14| = 3

1+12 = |13-14| = 1

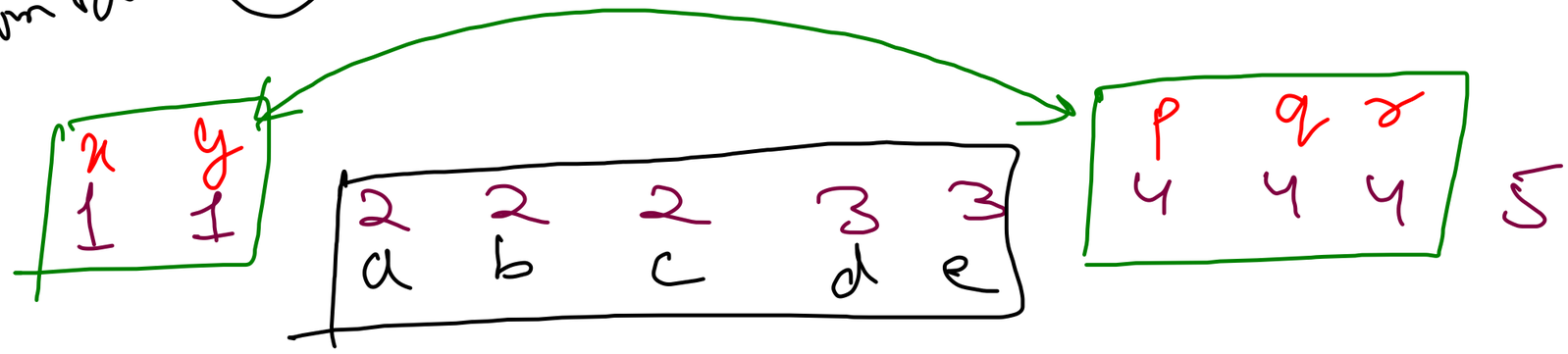
5+12 = |17-14| = 3

5+10 = |15-14| = 1

5+7 = |12-14| = 2

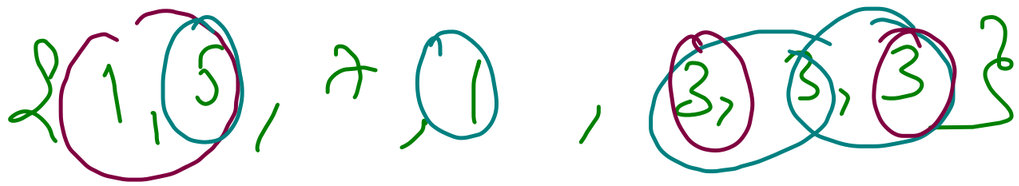
GFG
Target Sum Pair (11)

target = 5



(x,p) (x,q) (x,r) (a,d) (b,d) (c,d) 1f * 4f = 2 * 3

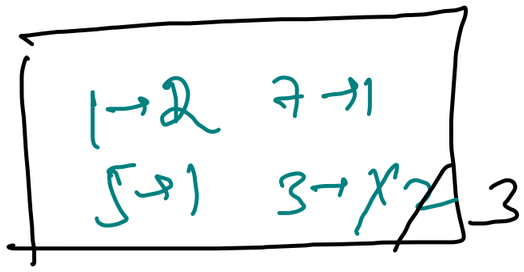
(y,p) (y,q) (x,r) (a,e) (b,e) (c,e) 2f * 3f = 3 * 2



target = 6

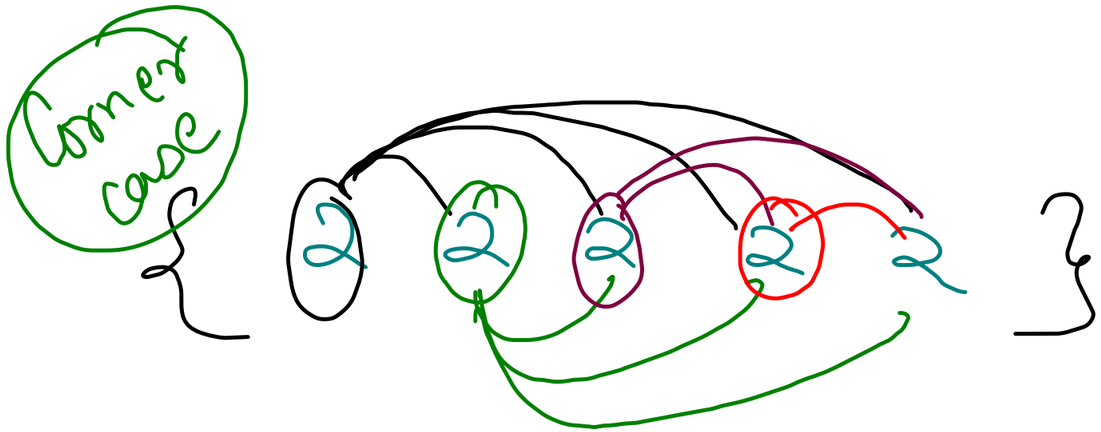
```java
HashMap<Integer, Integer> hm = new HashMap<>();

int count = 0;
for(int i=0; i<n; i++){
    int comp = target - arr[i];
    int freq = hm.getOrDefault(comp, 0);

    count += freq;
    hm.put(arr[i], hm.getOrDefault(arr[i], 0) + 1);
}

return count;
```

S->O(N) extra space



count = 0 1 2 3 5

O(N) time



$f[2] = 5$

$(n-1) + (n-2) + (n-3) + \cdots 1 = \boxed{\frac{n*(n-1)}{2}}$

complement == ele

target = 4

Target Sum Pair (IV) [Repeating]

1	5	6
8	10	11
15	16	18

2D to 1D

1 5 6 8 10 11 15 16 18

idx → 4

4 → 1 (4/3) , 1 (4%3)

mxidx = idx/cols

colidx = idx%cols

target = 21

2	4	7
9	10	12
13	16	20

2D to 1D

2 4 7 9 10 12 13 16 20

{1,20} { 5,16} { 8, 13} {11,10}

609 LintCode

2 Sum - smaller or equal

1 3 4 10 12 15

target $\leq$ (14)

$= 14$

< 14

1+15 > 14

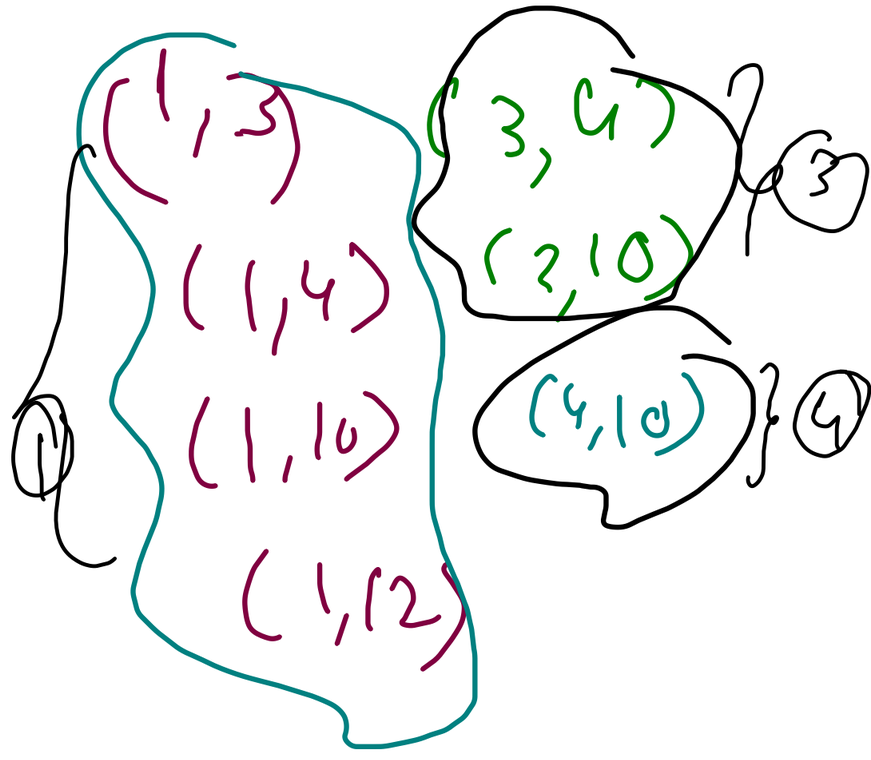
↑ 1+12 < 14 ⇒ (4)

3+12 > 14

↑ 3+10 < 14 ⇒ (2)

4+10 = 14 ⇒ (1)

```java
public int twoSum5(int[] nums, int target) {
    Arrays.sort(nums);
    int left = 0, right = nums.length - 1;

    int count = 0;
    while(left < right){
        int sum = nums[left] + nums[right];

        if(sum <= target){
            count += right - left;
            left++;
        } else {
            right--;
        }
    }

    return count;
}
```



443 lintcode

2 Sum - Greater

1 1 3 4 10 12 15

```
Arrays.sort(nums);
int left = 0, right = nums.length - 1;

int count = 0;
while(left < right){
    int sum = nums[left] + nums[right];

    if(sum <= target){
        left++;
    } else {
        count += right - left;
        right--;
    }
}

return count;
```

target > 14

(1,15)
(3,15)
(4,15)
(10,15)
} 15

(12,15)

(3,12)
(4,12)
(10,12)
} 12

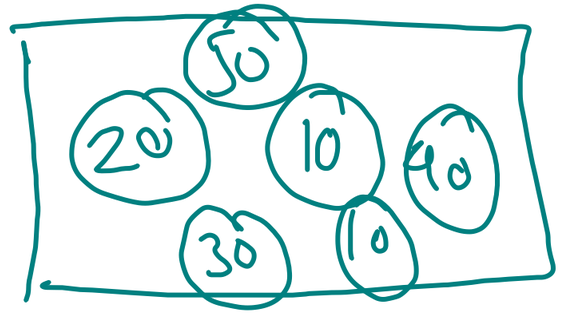
Two Sum - Design / Stream / Online

Algorithm

Design and implement a TwoSum class. It should support the following operations: `add` and `find`.

`add` - Add the number to an internal data structure.

`find` - Find if there exists any pair of numbers which sum is equal to the value.



1. add (20)
2. find (40) = False
3. add (10)
4. add (30)
5. add (40)
6. find (50) = True
7. find (40) = True
8. add (10)
9. add (50)
10. find (90) = True

① ArrayList

- add
  - ① Add (cost-) ⇒ O(nlogn)
  - ② Sort
- find
  - Two pointer ⇒ O(N)

② ArrayList

- add → addLast ⇒ O(1)
- find
  - if sorted → two pointer ⇒ O(N)
  - else
    - Sort
    - two pointer

⇒ O(nlogn)

```java
public class TwoSum {
    ArrayList<Integer> data;
    boolean isSorted;

    public TwoSum(){
        data = new ArrayList<>();
        isSorted = true;
    }

    public void add(int number) {
        data.add(number);
        isSorted = false;
    }

    public boolean find(int value) {
        if(isSorted == false){
            Collections.sort(data);
            isSorted = true;
        }

        int left = 0, right = data.size() - 1;
        while(left < right){
            int sum = data.get(left) + data.get(right);
            if(sum == value) return true;
            if(sum < value) left++;
            else right--;
        }
        return false;
    }
```

(3) Ordered — Map

Self Balancing BST

add → add in order → O(log N)

find → Two pointers → O(N)

Java code → Tree Map ⇓ next(), hasNext()

C++ code

```cpp
map<int, int> arr;

void add(int number) {
    arr[number]++;
}

bool find(int value) {
    auto left = arr.begin();
    auto right = arr.end();
    right--;

    while(left != right)
    {
        int sum = left->first + right->first;
        if(sum == value)
            return true;
        if(sum < value) left++;
        else right--;
    }

    if(left->second > 1 && 2 * (left->first) == value)
        return true;
    return false;
}
```

④ Hashmap of frequency

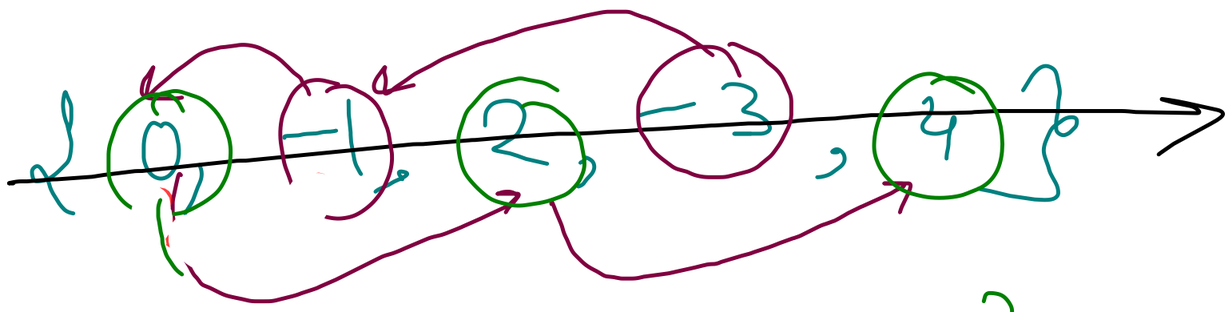
add → frequency update → { O(1) avg case, O(N) worst case (collisions)

find → checking complement by iterating on hashmap → O(N)

Corner case → equal complement → freq >= 2

```java
public class TwoSum {
    HashMap<Integer, Integer> freq;

    public TwoSum(){
        freq = new HashMap<>();
    }

    public void add(int number) {
        freq.put(number, freq.getOrDefault(number, 0) + 1);
    }

    public boolean find(int value) {
        for(Integer key: freq.keySet()){
            int comp = value - key;
            int freq_comp = freq.getOrDefault(comp, 0);

            if(value - key == key){
                if(freq_comp >= 2) return true;
            } else {
                if(freq_comp >= 1) return true;
            }
        }
        return false;
    }
}
```

Two Sum - Absolute (lintcode 587) (HW)



int left = ?, right = ?

{-3, 4} {-1, 2}