Bit Manipulation

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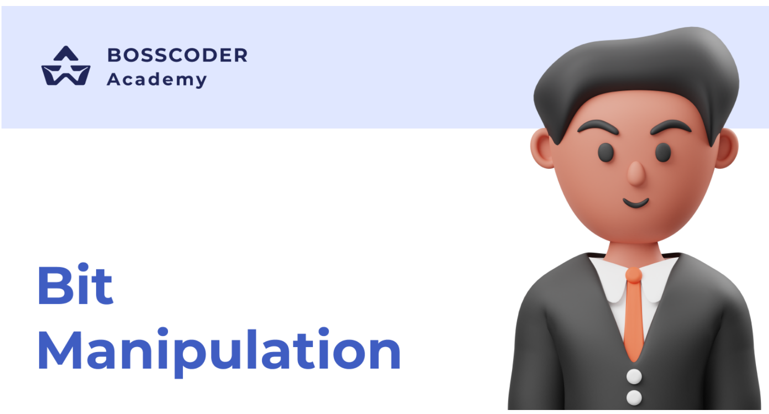

Agenda

1. Bit Manipulation Basics and different type of Bit Operators
2. Problems

Bit Manipulation

Bit manipulation is the process of applying logical operations on a sequence of bits to achieve a required result.

List of Bitwise operators

&	Bitwise AND
|	Bitwise OR
^	Bitwise XOR
~	Bitwise NOT
<<	Bitwise left shift
>>	Bitwise right shift

Bitwise AND -A & B

Values for bit combinations

a b a & b

----

0 0 0
0 1 0
1 0 0
1 1 1

Example:
A = 21 (10101) and B = 6 (110)
A & B =1 0 1 0 1 & 0 0 1 1 0= 4.

Bitwise OR-A|B

Values for bit combinations

a b a | b

----

0 0 0

1 1 1

Example:

A = 21 (10101) OR B = 6 (110)

A & B =1 0 1 0 1 | 0 0 1 1 0= 23.

Bitwise XOR-A^B

Values for bit combinations

a	b	a ^ b
0	0	0
0	1	1
1	0	1
1	1	0

Example:

A = 21 (10101) XOR B = 6 (110)

A ^ B =1 0 1 0 1 ^ 0 0 1 1 0= 19.

Right Shift Operators- A>>B

`A >> x` implies shifting the bits of A to the right by x positions. The last x bits are lost this way.

Example

A = 29 (11101) and x = 2,

so A >> 2 means

0 0 1 1 1 **0 1** >> 2

01 is lost and the rest of the digit shift to the right

0 0 0 0 1 1 1 = 7

`A >> x` is equal to division by pow(2, x)

Left Shift Operators- A<<B

`A << x` implies shifting the bits of A to the left by x positions. The first x bits are lost this way.

Example

0 0 1 1 1 0 1 >> 2

00 is lost and the rest of the digit shifts to the left

1 1 1 0 1 0 0=116

`A << x` is equal to multiplication by pow(2, x)

Property

1. A& B & C=A&(B&C)=(A&B)&C
2. A |B | C=A|(B|C)==(A|B)|C
3. A ^B ^ C=A^(B ^ C)==(A ^ B) ^ C

Problems

1. **Kth Bit is set or not**

   Given a number N and a bit number K, check if the K^{th} bit of N is set or not. A bit is called set if it is 1.

   Example

   Input: n = 5, k = 1

   Output: SET

   Explanation: 5 is represented as 101 in binary and has its first bit set.

   Approach 1

   Check whether the K-th bit is set or not Using Left Shift Operator

   Left shift given number 1 by k to create a number that has only set a bit as kth bit.temp = 1 << k If **bitwise AND of n and temp** is non-zero, then result is SET else result is NOT SET.

   Implementation

```
#include <bits/stdc++.h>
using namespace std;
```

```
    if (n & (1 << k))
        cout << "SET";
    else
        cout << "NOT SET";
}

int main()
{
    int n, k;
    cin >> n >> k;
    isKthBitSet(n, k);
    return 0;
}
```

Approach 2
Check whether the K-th bit is set or not Using Right Shift Operator:

If we right shift n by k, we get the last bit as 1 if the Kth bit is set else 0

Implementation

```
#include <bits/stdc++.h>
using namespace std;

void isKthBitSet(int n, int k)
{
    if ((n>>k) & (1))
        cout << "SET";
    else
        cout << "NOT SET";
}

int main()
{
```

```
    isKthBitSet(n, k);
    return 0;
}
```

Time Complexity: O(1)
Space Complexity: O(1)

2. **Least Significant Bit which is set**
Find the position of the first 1 from right to left, in the binary representation of an Integer.
Examples:
Input: n = 18
Output: 2
Explanation: Binary Representation of 18 is 010010, hence the position of the first set bit from the right is 2.
Approach
Start from 0 positions and iterate till the 32nd-bit position if any bit is 1 break the loop and print the index else move left till 32.
Implementation

```
#include <bits/stdc++.h>
using namespace std;

int PositionRightmostSetbit(int n)
{
     if (n == 0)
    {
        return 0;
    }
    else {
        int pos = 1;
        for (int i = 0; i < 32; i++) {
```

```
            else
                break;
        }
        return pos;
    }
}

int main()
{
    int n;
    cin>>n;
    cout << PositionRightmostSetbit(n);
    return 0;
}
```

Time Complexity: O($\log_2$n), Traversing through all the bits of N, where at max there are logN bits.
Space Complexity: O(1)

3. [Find the element that appears once rest of the element appears twice]()

Given an array of integers. All numbers occur twice except one number which occurs once. Find the number.
Example :
Input: n=7, arr[] = {2, 3, 5, 4, 5, 3, 4}
Output: 2

Brute Force Method

Check every element if it appears once or not. Once an element with a single occurrence is found, return it.

Implementation

```
int SingleOccuringELement(int a[], int n)
{
    for (int i = 0; i < n; i++)
    {
        int count = 0;
        for (int j = 0; j < n; j++)
        {

            if (a[i] == a[j])
            {
                count++;
            }
        }
        if (count == 1)
        {
            return a[i];
        }
    }

    return -1;
}

int main()
{
    int n;
    cin >> n;
    int a[n];
    for (int i = 0; i < n; i++)
        cin >> a[i];
    cout << SingleOccuringELement(a, n);
    return 0;
}
```

frequency of the elements and after that, we can iterate the hashmap to find the element with frequency 1.

Implementation

```
#include <bits/stdc++.h>
using namespace std;

int SingleOccuringELement(int a[],int n)
{
   unordered_map<int,int> mm;
      for(int i=0;i<n;i++)
     {
           mm[a[i]]++;
     }
      for(auto x:mm)
     {
           if(x.second==1) return x.first;
     }
}

int main()
{
    int n;
    cin>>n;
    int a[n];
    for(int i=0;i<n;i++) cin>>a[i];
    cout << SingleOccuringELement(a,n);
    return 0;
}
```

Bitwise Based Approach

The best solution is to use XOR. XOR of all array elements gives us the number with a

1. XOR of a number with itself is 0.
2. XOR of a number with 0 is the number itself.

Implementation

```
#include <bits/stdc++.h>
using namespace std;

int SingleOccuringELement(int a[],int n)
{
    int res = a[0];
    for (int i = 1; i < n; i++)
        res = res ^ a[i];

    return res;
}

int main()
{
    int n;
    cin>>n;
    int a[n];
    for(int i=0;i<n;i++) cin>>a[i];
    cout << SingleOccuringELement(a,n);
    return 0;
}
```

Time Complexity: O(n)
Space Complexity: O(1)

4. [Find element occuring once when all others are present thrice]()

Given an array of integers **arr[]** of length N, every element appears thrice except for one which occurs once.

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Input: N = 4 arr[] = {1, 10, 1, 1}

Output: 10

Approach

We will traverse for every bit position in all the numbers if the bit is 1 for any number that appears thrice then it will be divisible by 3 if it is not then the number that appears once has it's a bit as 1 there so we can get the number that appears once using this concept.

Implementation

```
#include <bits/stdc++.h>
using namespace std;

int SingleOccuringELement(int a[],int n)
{
   int ans=0;
        for(int i=0;i<32;i++)
        {
            int bit=1<<i;
            int c=0;
            for(int j=0;j<n;j++)
            {
                if(a[j]&bit)
                c++;
            }
            if(c%3)
            ans|=bit;
        }
        return ans;
}

int main()
{
```

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```
    int a[n];
    for(int i=0;i<n;i++) cin>>a[i];
    cout << SingleOccuringELement(a,n);
    return 0;
}
```

Time Complexity: O(N)
Space Complexity: O(1)

5. **Find the two non-repeating elements in an array of repeating elements**
Given an array in which all numbers except two are repeated once. Find those two numbers.
Example
Input: n=6 ,a[]={1,1,2,2,3,4}
Output:3,4
Method 1(Use Sorting)
First, sort all the elements. In the sorted array, by comparing adjacent elements we can easily get the non-repeating elements.
Implementation

```
#include <bits/stdc++.h>
using namespace std;

vector<int> SingleOccuringELementTwo(int a[
{
   sort(a, a + n);

    vector<int> ans;
    for (int i = 0; i < n - 1; i = i + 2) {
        if (a[i] != a[i + 1]) {
            ans.push_back(a[i]);
```

```
    }

    if (ans.size() == 1)
        ans.push_back(a[n - 1]);

    return ans;
}

int main()
{
    int n;
    cin>>n;
    int a[n];
    for(int i=0;i<n;i++) cin>>a[i];
      vector<int>ans=SingleOccuringELement1
   cout<<ans[0]<<" "<<ans[1]<<endl;
    return 0;
}
```

Method 2(Use XOR)

Let x and y be the non-repeating elements we are looking for and arr[] be the input array. First, calculate the XOR of all the array elements. All the bits that are set in xor will be set in one non-repeating element (x or y) and not in others. So if we take any set bit of xor and divide the elements of the array into two sets – one set of elements with the same bit set and another set with the same bit not set. By doing so, we will get x in one set and y in another set. Now if we do XOR of all the elements in the first set, we will get the first non-repeating element, and by doing the same in other sets we will get the second non-

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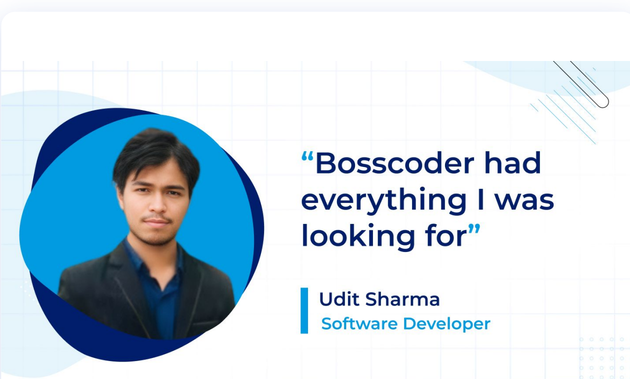
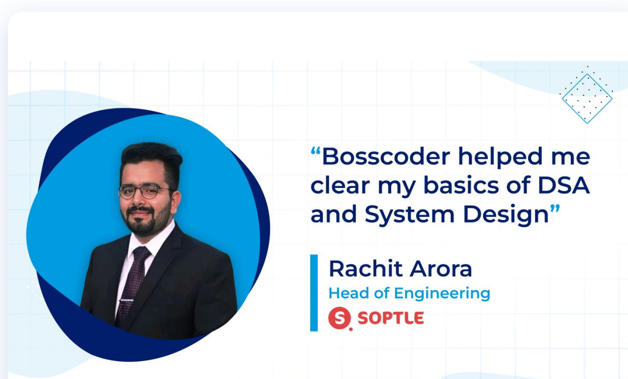
```
#include <bits/stdc++.h>
using namespace std;

void SingleOccuringELementTwo(int a[], int
{
    int Xor = a[0];

    int set_bit_no;
    int i;
    int x = 0;
    int y = 0;
    for (i = 1; i < n; i++)
        Xor ^= a[i];
    set_bit_no = Xor & ~(Xor - 1);
    for (i = 0; i < n; i++)
    {
        if (a[i] & set_bit_no)
            x = x ^ a[i];
        else
        {
            y = y ^ a[i];
        }
    }
    cout << x << " " << y;
}

int main()
{
    int n;
    cin >> n;
    int a[n];
    for (int i = 0; i < n; i++)
        cin >> a[i];
```

```
    return 0;
}
```

Time Complexity: O(n)
Space Complexity: O(1)





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