260. Single Number III (/problems/single-number-iii/)

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Given an array of numbers `nums`, in which exactly two elements appear only once and all the other elements appear exactly twice. Find the two elements that appear only once.

Example:

```
Input:  [1,2,1,3,2,5]
Output: [3,5]
```

Note:

1. The order of the result is not important. So in the above example, `[5, 3]` is also correct.
2. Your algorithm should run in linear runtime complexity. Could you implement it using only constant space complexity?

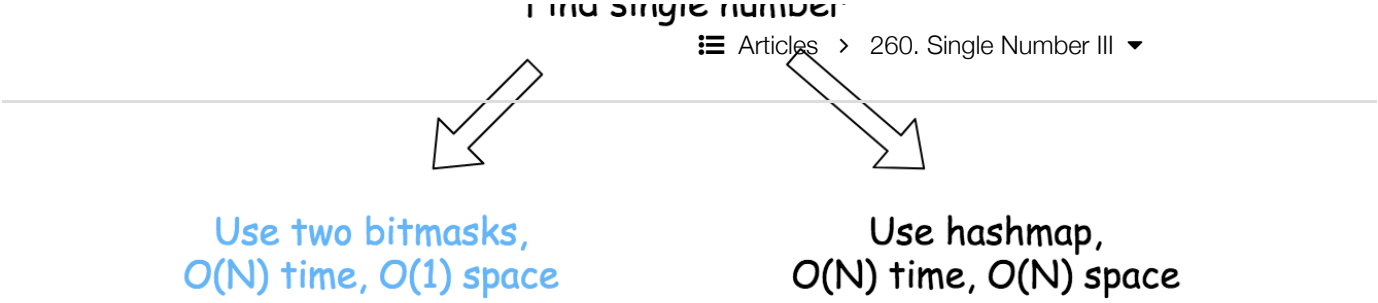
Solution

Overview

The problem could be solved in $\mathcal{O}(N)$ time and $\mathcal{O}(N)$ space by using hashmap.

To solve the problem in a constant space is a bit tricky but could be done with the help of two bitmasks.

Find single number



Approach 1: Hashmap

Build a hashmap : element -> its frequency. Return only the elements with the frequency equal to 1.

Implementation

Java Python Copy

```
1  from collections import Counter
2  class Solution:
3      def singleNumber(self, nums: int) -> List[int]:
4          hashmap = Counter(nums)
5          return [x for x in hashmap if hashmap[x] == 1]
```

Complexity Analysis

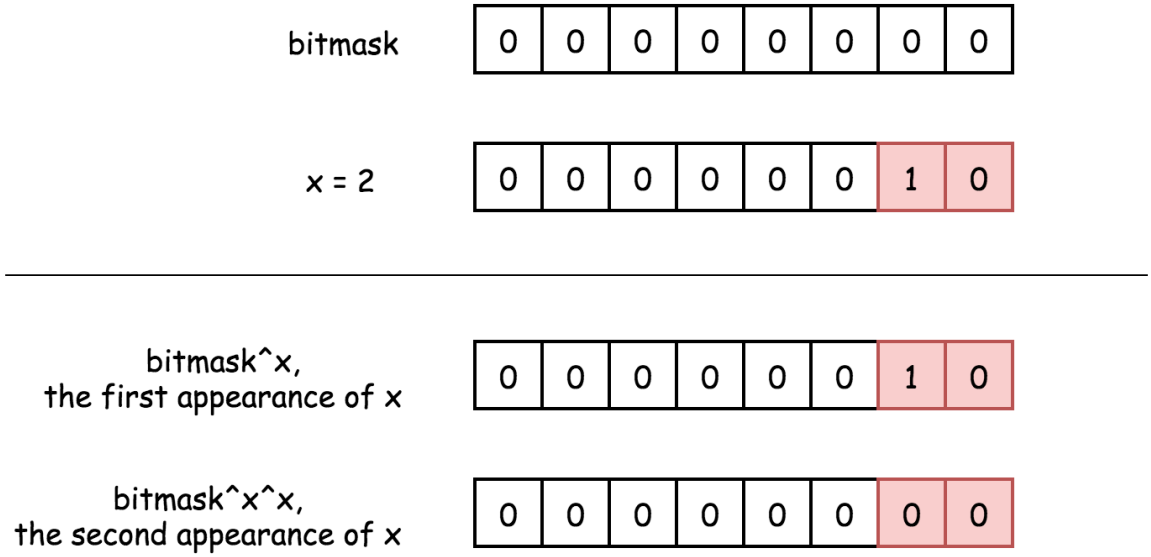
- Time complexity : $\mathcal{O}(N)$ to iterate over the input array.
- Space complexity : $\mathcal{O}(N)$ to keep the hashmap of N elements.

Approach 2: Two bitmasks

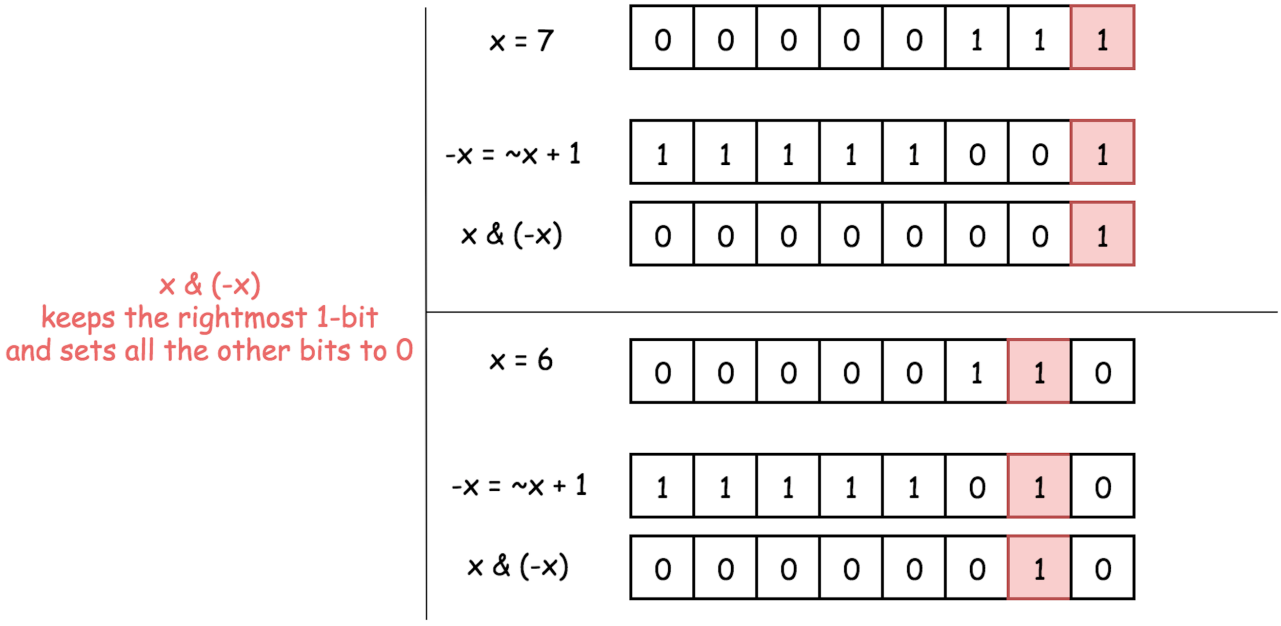
Prerequisites

This article will use two bitwise tricks, discussed in details last week :

- If one builds an array bitmask with the help of XOR operator following `bitmask ^= x` strategy, the bitmask would keep only the bits which appear odd number of times. That was discussed in details in the article Single Number II (https://leetcode.com/articles/single-number-ii/).



- `x & (-x)` is a way to isolate the rightmost 1-bit, i.e. to keep the rightmost 1-bit and to set all the others bits to zero. Please refer to the article Power of Two (https://leetcode.com/articles/power-of-two/) for the detailed explanation.

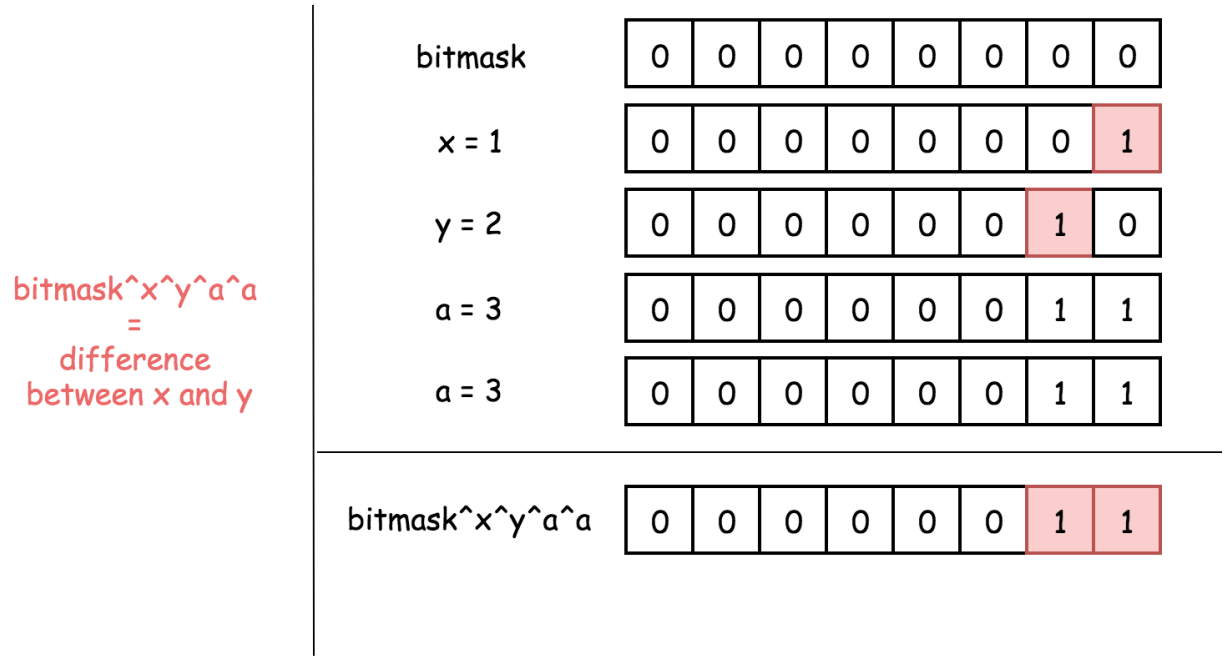


Intuition

> An interview tip. Imagine, you have a problem to indentify an array element (or elements), which appears exactly given number of times. Probably, the key is to build first an array bitmask using XOR operator. Examples: In-Place Swap (leetcode.com/articles/single-number-ii/356460/Single-Number-II/324042), Single Number (https://leetcode.com/articles/single-number/), Single Number II (leetcode.com/articles/single-number-ii/356460/Single-Number-II/324042).

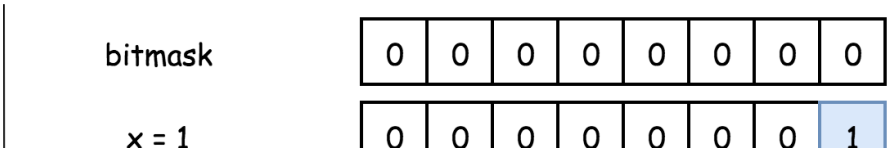
So let's create an array bitmask : `bitmask ^= x`. This bitmask will *not* keep any number which appears twice because XOR of two equal bits results in a zero bit `a^a = 0`.

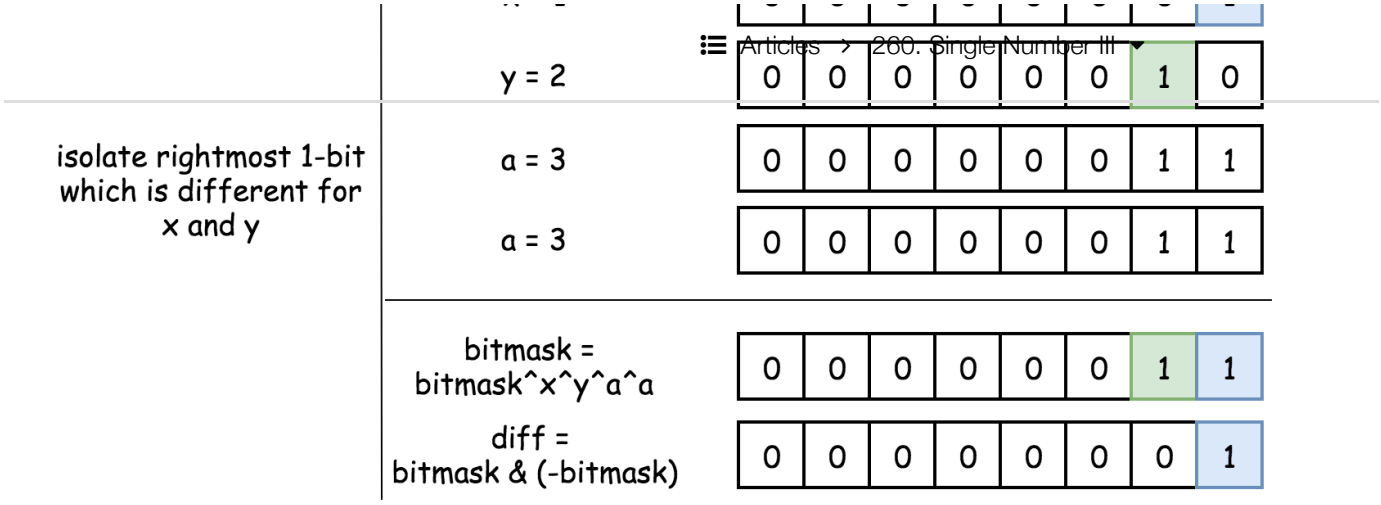
Instead, the bitmask would keep only the difference between two numbers (let's call them x and y) which appear just once. The difference here it's the bits which are different for x and y.



> Could we extract x and y directly from this bitmask? No. Though we could use this bitmask as a marker to separate x and y.

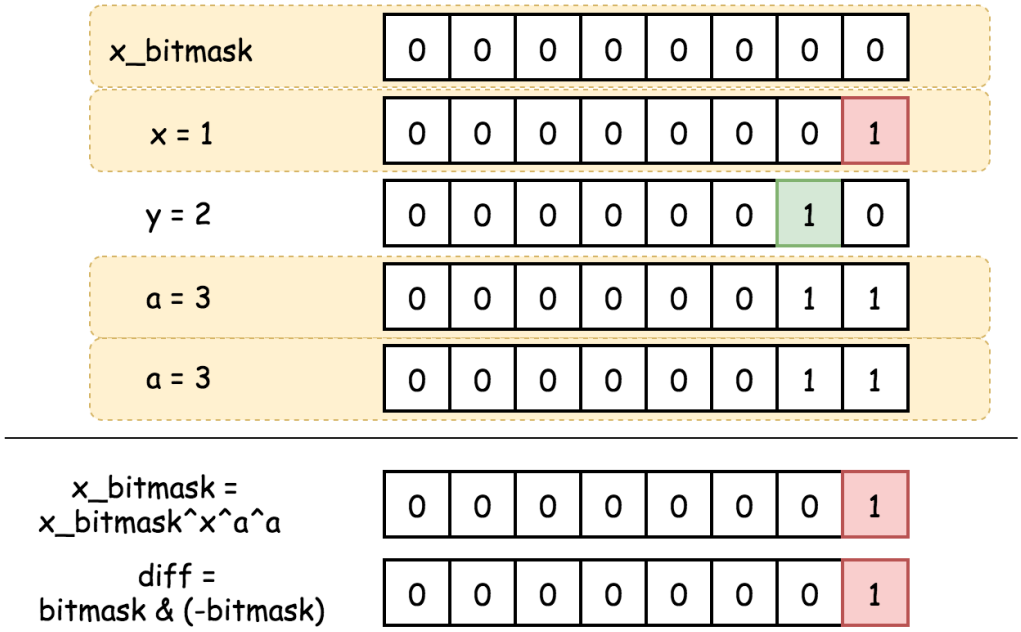
Let's do `bitmask & (-bitmask)` to isolate the rightmost 1-bit, which is different between x and y. Let's say this is 1-bit for x, and 0-bit for y.





Now let's use XOR as before, but for the new bitmask `x_bitmask`, which will contain only the numbers which have 1-bit in the position of `bitmask & (-bitmask)`. This way, this new bitmask will contain only number x `x_bitmask = x`, because of two reasons:

- y has 0-bit in the position `bitmask & (-bitmask)` and hence will not enter this new bitmask.
- All numbers but x will not be visible in this new bitmask because they appear two times.



Voila, x is identified. Now to identify y is simple: `y = bitmask^x`.

Implementation

Java | Python

Articles > 260. Single Number III

Copy

```python
class Solution:
    def singleNumber(self, nums: int) -> List[int]:
        # difference between two numbers (x and y) which were seen only once
        bitmask = 0
        for num in nums:
            bitmask ^= num

        # rightmost 1-bit diff between x and y
        diff = bitmask & (-bitmask)

        x = 0
        for num in nums:
            # bitmask which will contain only x
            if num & diff:
                x ^= num

        return [x, bitmask^x]
```

Complexity Analysis

- Time complexity : $\mathcal{O}(N)$ to iterate over the input array.
- Space complexity : $\mathcal{O}(1)$, it's a constant space solution.

Analysis written by @liaison (https://leetcode.com/liaison/) and @andvary (https://leetcode.com/andvary/)

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```
nums = [1,2,1,3,2,5]
seen = []
for num in nums:
    if num in seen:
```

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