374. Guess Number Higher or Lower

Easy | Binary Search | Interactive | Leetcode Link

Problem Description

In the Guess Game, you have to guess a number chosen by the game from a range of numbers starting from `1` to `n`. The game's goal is to find the number selected by the game with the help of a clue provided after each guess. When you make a guess by choosing a number within the range, the game responds by indicating if your guess is higher, lower, or equal to the secret number it has chosen. The responses are given through a pre-defined `guess` function with the following possible return values:

- If your guess is too high, the function returns `-1`.
- If your guess is too low, the function returns `1`.
- If your guess is correct, meaning it matches the secret number, the function returns `0`.

Your task is to use this `guess` function to determine and return the secret number the game has picked.

Intuition

The straightforward approach to solving this problem would involve using a binary search method. Since the potential numbers range from `1` to `n`, we can start by guessing in the middle of this range. Depending on the feedback from the `guess` function, we would know if the target number is higher or lower than our current guess, and we would adjust our search range accordingly, narrowing it down until we find the exact number.

However, this solution uses a specialized Python library called `bisect` that is capable of performing binary search operations efficiently. Here's the intuition behind the approach in the solution provided:

- `bisect.bisect`: This is a function from the `bisect` module which is used to find a position in a list where an element should be inserted to keep the list sorted.
- Since we know the `guess` function returns `-1` if our guess is high and `1` if our guess is low, we can use this information as a key function for the `bisect` method. By negating the `guess` function in the key, we essentially transform the `guess` function's return value to use it for `bisect`.
- The `range` function generates a sequence of numbers, which represents our possible guesses.
- By using `bisect` with the negated `guess` as a key, it will effectively perform a binary search to find the correct position, i.e., where the return value of the `guess` function would be `0`, which means the guess matches the picked number.

In doing so, the solution code bypasses the more common iterative or recursive implementations of binary search and instead uses the `bisect` library to find the solution, showing yet another powerful aspect of Python's standard library.

Solution Approach

The implementation of the provided solution uses the `bisect` module from Python, which is designed to make binary searches simple and efficient. Here's the breakdown of the solution approach:

1. **Leveraging Python's Standard Library**: The `bisect` module contains two main functions — `bisect_left` and `bisect_right` (or just `bisect` as an alias for `bisect_right`), which are used for binary search.

2. **Understanding the bisect function**: The `bisect.bisect` function is used to find the insertion point for a given element in a sorted list to maintain the sorted order. This means that it can be used to find where in the list a new element should go such that the list will still be in order.

3. **Applying bisect with a key function**: In this problem, the `bisect` function is given a key argument, which is a function that will be called on each element in the array before making comparisons during the binary search. Here, the key function is a lambda function that returns the negated result of the `guess` function: `lambda x: -guess(x)`. The negation is useful because `bisect` is typically used for finding insertion points and expects the condition to be sorted in ascending order. Since a correct guess returns `0`, when we negate `0`, it remains `0`, which `bisect` would interpret as the correct insertion point or, in our case, the correctly guessed number.

4. **Using the range**: The `range` function, `range(1, n + 1)`, creates a sequence of numbers starting from `1` to `n`. This range represents the entire list of potential guesses.

5. **Finding the correct guess**: The `bisect.bisect` function is called with the range and key function defined above. It will effectively perform a binary search over this range, using the key function to compare the guess to the secret number until the insertion point (where the guess is correct) is located.

6. **Returning the correct number**: The function will return the position where the `guess(x)` is `0`, which is the selected number.

The algorithm used in this solution has an average-case and worst-case time complexity of O(log n) because it is a binary search algorithm. It works by essentially cutting down the search space by half with each incorrect guess that it makes, thereby narrowing in on the correct number with each iteration.

Overall, this is an elegant approach that takes full advantage of Python's capabilities, providing an alternative to the more manually implemented binary search algorithm.

Example Walkthrough

Let's assume the secret number the game has picked is `6` and our range `n` is `10`. We will use the provided solution approach leveraging the `bisect` module to find this secret number.

1. **Setting Up the Problem**: The game has chosen a secret number from `1` to `10`, and our guess should be within this range. Let's illustrate the binary search mechanism step by step.

2. **First Iteration**: The middle of our range `1` to `10` is `5.5` (we would round this to `6` in implementation, but let's follow the strict binary process). We guess `5` as our first attempt (since we typically use integer division which truncates the decimal). The `guess` function returns `1` since our guess is lower than the secret number.

3. **Adjusting the Range**: With the feedback that our guess was too low, we adjust our range from `6` to `10`. The new middle of this range is `8`.

4. **Second Iteration**: We now guess `8`, and the `guess` function returns `-1` indicating our guess is higher than the secret number.

5. **Narrowing Down Further**: The secret number is, therefore, between `6` and `7` (since we've ruled out `8` and above). The new middle point is `6.5`, so our next guess will be `6`.

6. **Third Iteration and Correct Guess**: Guessing `6`, the `guess` function returns `0`, signalling that we've found the correct number.

Throughout this process, if we were using `bisect.bisect` with the negated `guess` function as the key, it would have negated the return values of the `guess` function and performed these steps internally. We wouldn't actually see the returned values of `1` or `-1`; `bisect` would use them to perform the binary search:

- At the first iteration, with the middle element as `5` and the `guess` function returning `1` (guess too low), negating it gives us `-1`, which guides the search to go higher.
- At the second iteration, with the middle element as `8` and the `guess` function returning `-1` (guess too high), negating it gives us `1`, which guides the search to go lower.
- Finally, at the correct guess `6`, the `guess` function returns `0`, and negated or not, it remains `0`, indicating the correct position has been found.

So with the `bisect.bisect` function, the correct number `6` would be returned as the position where the `guess(x)` equates to `0`. This example walkthrough illustrates how the binary search and, by extension, the `bisect` function would find the secret number chosen by the game.

Python Solution

```python
# The guess API is already defined for you.
# @param num, your guess
# @return -1 if num is higher than the picked number
#          1 if num is lower than the picked number
#          otherwise return 0
# def guess(num: int) -> int:

import bisect

class Solution:
    def guessNumber(self, n: int) -> int:
        # Use binary search to find the guessed number.
        # Define the bisect function to compare guess results.
        def guess_compare(x):
            # Return the result of the guess API call:
            # Negative result if our guess is higher (-1),
            # Positive if our guess is lower (1),
            # Zero if our guess is correct (0)
            return -guess(x)

        # Use the bisect function to find the correct number.
        # We make use of the `key` parameter to provide our custom comparison
        # function which uses the guess API as the comparison logic.
        return bisect.bisect_left(range(1, n + 1), 0, key=guess_compare)

# Note: The original implementation used bisect.bisect, which by default assumes
# an insertion point that would maintain order. In this case, we want the exact position
# where the guess result is 0, hence bisect_left is more appropriate.
```

Java Solution

```java
/**
 * This class is an extension of the GuessGame class which contains a guess API method.
 * The guessNumber method aims to find the number which the API is thinking of.
 */
public class Solution extends GuessGame {
    /**
     * Guesses the number by using binary search to minimize the number of calls to the guess API.
     *
     * @param  n  the upper bound of the range to search.
     * @return    the number that matches the guess API's hidden number.
     */
    public int guessNumber(int n) {
        // Initialize the lower bound of the search range.
        int left = 1;
        // Initialize the upper bound of the search range.
        int right = n;

        // Continue searching as long as the range has not been narrowed down to a single element.
        while (left < right) {
            // Calculate the midpoint of the current range to use as our guess.
            int mid = left + (right - left) / 2;

            // Make a guess using the midpoint and get the response from the guess API.
            int apiResponse = guess(mid);

            // If the guess is too high or correct, narrow the range to the lower half (inclusive of mid).
            if (apiResponse <= 0) {
                right = mid;
            } else {
                // If the guess is too low, narrow the range to the upper half (exclusive of mid).
                left = mid + 1;
            }
        }
        // When the loop exits, left and right converge to the target number; return it.
        return left;
    }
}
```

C++ Solution

```cpp
/**
 * The guessNumber function tries to find a secret number within a range between 1 and n.
 * It relies on a pre-defined API "guess" which takes an integer as an input (your guess) and returns
 * -1 if the guess is lower than the secret number, 1 if it is higher, and 0 when your guess matches the secret number.
 *
 * @param n An integer representing the upper bound of the range within which to guess the number.
 * @return The secret number.
 */

class Solution {
public:
    int guessNumber(int n) {
        int lowerBound = 1;  // Initialize lower bound of the search interval
        int upperBound = n;  // Initialize upper bound of the search interval

        // Perform a binary search in the interval from lowerBound to upperBound
        while (lowerBound < upperBound) {
            // Calculate the middle value in the current interval
            int mid = lowerBound + ((upperBound - lowerBound) >> 1); // Equivalent to (lowerBound + upperBound) / 2 but avoids overfl

            // Use the guess API method to compare the middle value with the secret number
            if (guess(mid) <= 0) {
                // If the guess is greater than or equal to the secret number, narrow the search to the lower half
                upperBound = mid;
            } else {
                // If the guess is less than the secret number, narrow the search to the upper half
                lowerBound = mid + 1;
            }
        }

        // At this point, lowerBound == upperBound, and we have found the secret number
        return lowerBound;
    }
};
```

Typescript Solution

```typescript
// Forward declaration of the guess API.
// @param {number} num - Your guess
// @return -1 if num is lower than the guess number
// @return 1 if num is higher than the guess number
// @return 0 if num is the guess number
declare function guess(num: number): number;

/**
 * Finds the number guessed by the guess API within the range [1, n].
 *
 * @param {number} n - The maximum range within which the guessed number falls.
 * @return {number} - The correct guessed number.
 */
function guessNumber(n: number): number {
    // Initialize the search range
    let left = 1;
    let right = n;

    // Use binary search to find the guessed number
    while (left < right) {
        // Calculate the midpoint to minimize the search range
        // Using right shift by 1 to ensure no overflow happens
        const mid = left + ((right - left) >>> 1);

        // Guess the middle of the range and reduce the range based on the response
        const result = guess(mid);
        if (result <= 0) {
            // If the guessed number is less than or equal to mid, narrow the range to the left half
            right = mid;
        } else {
            // If the guessed number is greater than mid, narrow the range to the right half
            left = mid + 1;
        }
    }
    // At the end of the loop, left should be equal to the guessed number
    return left;
}
```

Time and Space Complexity

The time complexity of the provided code is `O(log n)`. This is because the `bisect` function employed here uses a binary search algorithm to find the insertion point for `0` in the sorted sequence. It repeatedly divides the sequence in half to locate the position, which results in a logarithmic number of steps with respect to the sequence's length.

The space complexity of the code is `O(1)` since it uses a constant amount of extra space. The `key` function in the `bisect` function does not store any additional data structures related to the size of the input `n`, and the rest of the operations do not require more space that grows with the input size.