Memoized Fibonacci

We'll add yet another tool to our toolbelt in this lesson. We'll learn memoization, a technique of storing data that has already been computed for later use.

Fibonacci

We'll start with the simple version and create the advanced version further down.

Instructions

Write a function that will take a positive integer n and return an array of length n containing the Fibonacci sequence (https://en.wikipedia.org/wiki/Fibonacci_number).

Input: Integer > 0

Output: Array of Numbers

Examples

```
fibonacci(4); // -> [1, 1, 2, 3]
fibonacci(6); // -> [1, 1, 2, 3, 5, 8]
fibonacci(8); // -> [1, 1, 2, 3, 5, 8, 13, 21]
```

```
function fibonacci(n) {
    // Your code here
}
```

Solution 1

```
function fibonacci(n) {
    const seq = [1, 1];

    if(n < 2) {
        return seq.slice(0, n);
    }

    while(seq.length < n) {
        const lastItem = seq[seq.length - 1];
        const secondLastItem = seq[seq.length - 2];
        seq.push(lastItem + secondLastItem);
    }

    return seq;
}
```

How it Works

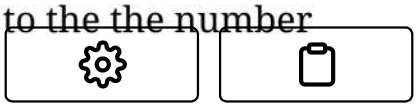
We store the sequence in `seq`. In the loop, we add up the previous two values in the array and push the sum into the array. We run the loop until we have the array length we want.

Time

Time complexity is:

O(n),

since the number of times the loop runs is proportional to the the number provided.



Space

Space complexity is also:

O(n),

as we need to store every value we calculate. There's no way around this, as it's required by the problem statement.

While we can't improve the time complexity of this solution, we can improve another aspect of it.

What happens if we want to call this function multiple times? Say we need to call it 10,000 times for very large input values. This could take some time.

What we can do is *save* the numbers we've already calculated so they don't need to be calculated again. This is called memoization (https://en.wikipedia.org/wiki/Memoization).

If you like, attempt this problem yourself. You'll have to think about how to store values after a function has completed running.

```
1  function fibonacci(n) {
2      // Your code here
3  }
```

Solution 2

```
1  const fibonacci = (function() {
2      const seq = [1, 1];
3
4      return function(n) {
5          if(seq.length >= n) {
6              return seq.slice(0, n);
7          }
8
9          while(seq.length < n) {
10             const lastItem = seq[seq.length - 1];
11             const secondLastItem = seq[seq.length - 2];
12             seq.push(lastItem + secondLastItem);
13         }
14
15         return seq;
16     }
17 })();
```

How it Works

IIFE

This version of our function is an IIFE (https://developer.mozilla.org/en-US/docs/Glossary/IIFE), or Immediately Invoked Function Expression. An IIFE is a function that is invoked immediately in order to make use of its return value.

Our main function, the one spanning lines 1 - 17, is anonymous. It has no name and exists only to be called once, immediately after its declaration.

What actually goes into the variable `fibonacci` is the *return value* of this IIFE. It's the function that starts on line 4 and that our large, outer function returns.

Scope Access

This returned function, `fibonacci`, retains access to the scope it was created in. Even after its outer IIFE has returned, it still has access to the array `seq`, and can use it internally. More importantly, `seq` stays in memory through multiple calls.

Inside the function, we check the array `seq`. If it has more values than we need, we slice the array and return a sliced array. If not, we calculate the number of values we need and add them to the array.

Stored Computations

`seq` has become a data store that our function can access whenever it needs. It allows our function to never perform the same calculation twice. Once our function calculates the sequence up to a certain length, it never has to do that math again.

We can see this if we add some `console.log` statements into our function.

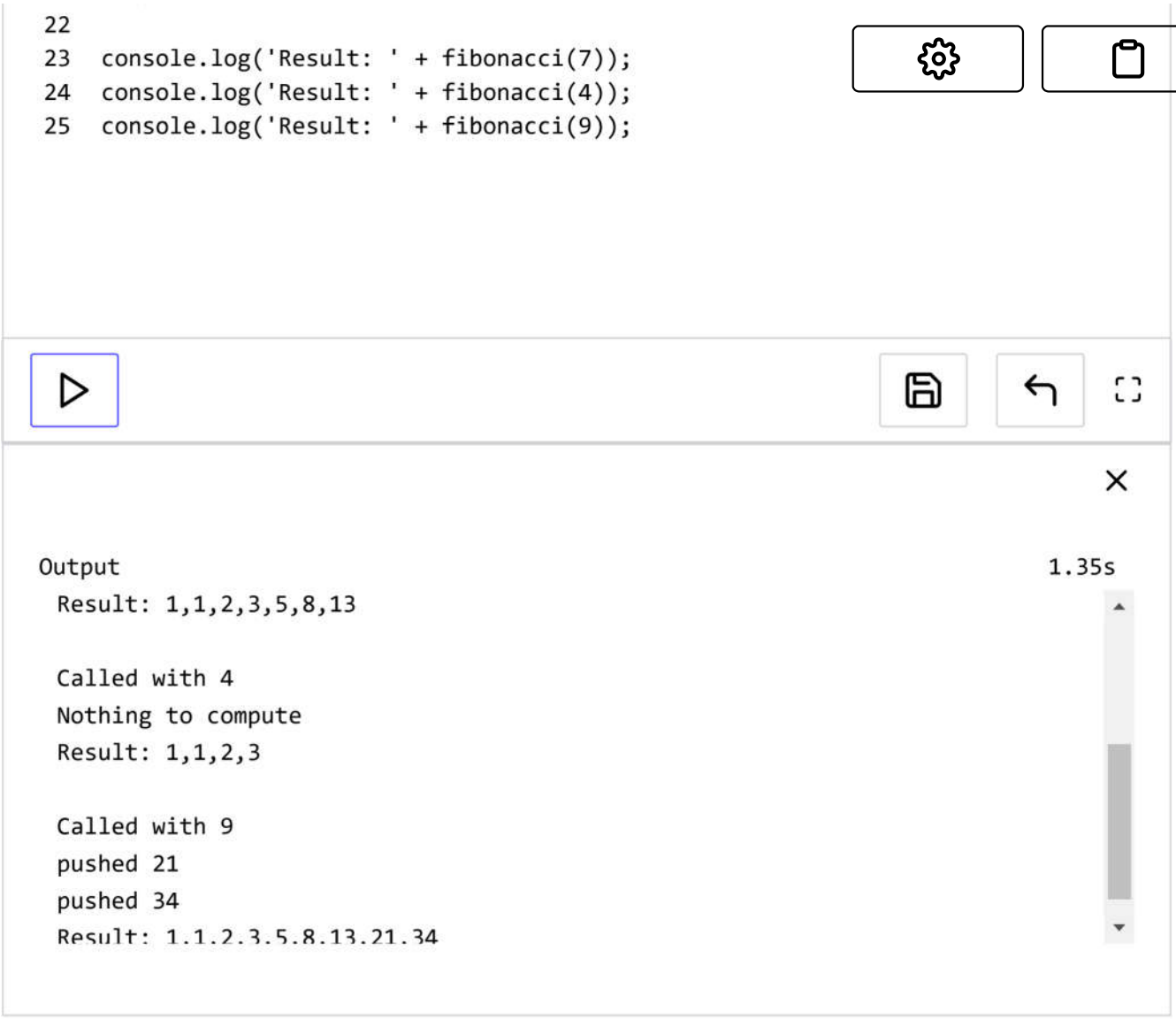
```
const fibonacci = (function() {
    const seq = [1, 1];

    return function(n) {
        console.log('\nCalled with ' + n);

        if(seq.length >= n) {
            console.log('Nothing to compute');
            return seq.slice(0, n);
        }

        while(seq.length < n) {
            const lastItem = seq[seq.length - 1];
            const secondLastItem = seq[seq.length - 2];
            seq.push(lastItem + secondLastItem);
            console.log(`pushed ${lastItem + secondLastItem}`);
        }

        return seq;
    }
})();
```



For the first call above, the function receives `7` and must calculate the whole sequence. For the second call, with `5`, no computations are necessary at all. The data already exists. For the last call, `9`, only two more numbers need to be calculated. The first 7 are stored.

Repeated Calls

Imagine calling our first solution 10,000 times with an input of `10,000`. Our function has to redo the same work over and over.

Now imagine running the same with our new function. The math will only occur once. Every subsequent call will use stored data.

Performance

Here is how long the first solution takes in Chrome Dev Tools, called 10,000 times with a value of `10,000`.

`console.time()` and `console.timeEnd()` are functions that allow us to time whatever operations we like.

```
> console.time('Naive Fibonacci');

  for(let i = 0; i < 10000; i++) {
      fibonacci(10000);
  }

  console.timeEnd('Naive Fibonacci');
  Naive Fibonacci: 779.5869140625ms
```

Solution 1, naive

It takes 780ms. Let's try with our second solution.

```
> console.time('Memoized Fibonacci');

  for(let i = 0; i < 10000; i++) {
      fibonacci(10000);
  }

  console.timeEnd('Memoized Fibonacci');
  Memoized Fibonacci: 146.686767578125ms
```

Solution 2, memoized

It takes 147ms, less than 1/5 of the time. We see some very real performance gains.

Conclusion

While we won't likely have to call a Fibonacci function repeatedly, there are situations in which memoization makes a sizable performance difference. It's an excellent technique to understand and to have in our toolbelt.

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