Unit 3: Algorithms

•••

Recursion

Roadmap

- What is recursion?
- Why use recursion?
- Types of Recursion

What is Recursion?

A function is recursive if...

It calls itself within its own definition!

It calls itself within its own definition!

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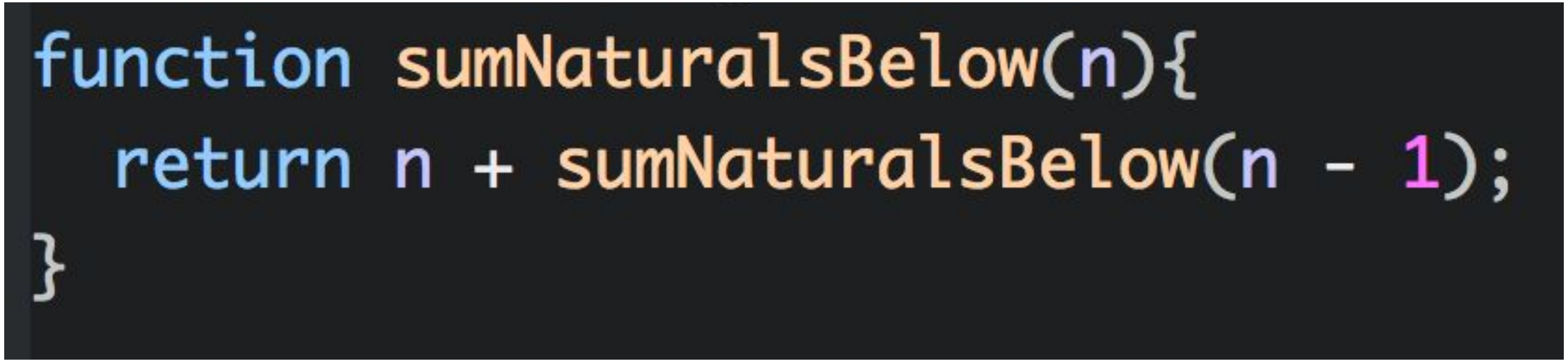
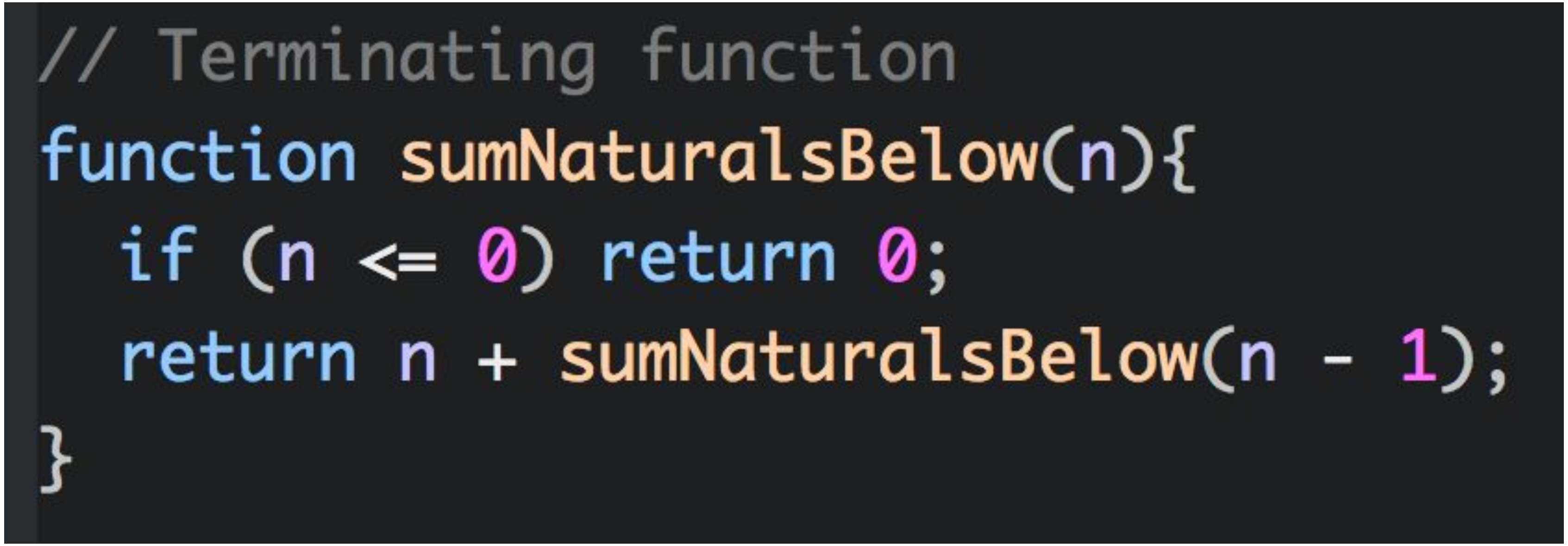
It calls itself within its own definition!

Consider the following function...



```
function sumNaturalsBelow(n){
  return n + sumNaturalsBelow(n - 1);
}
```

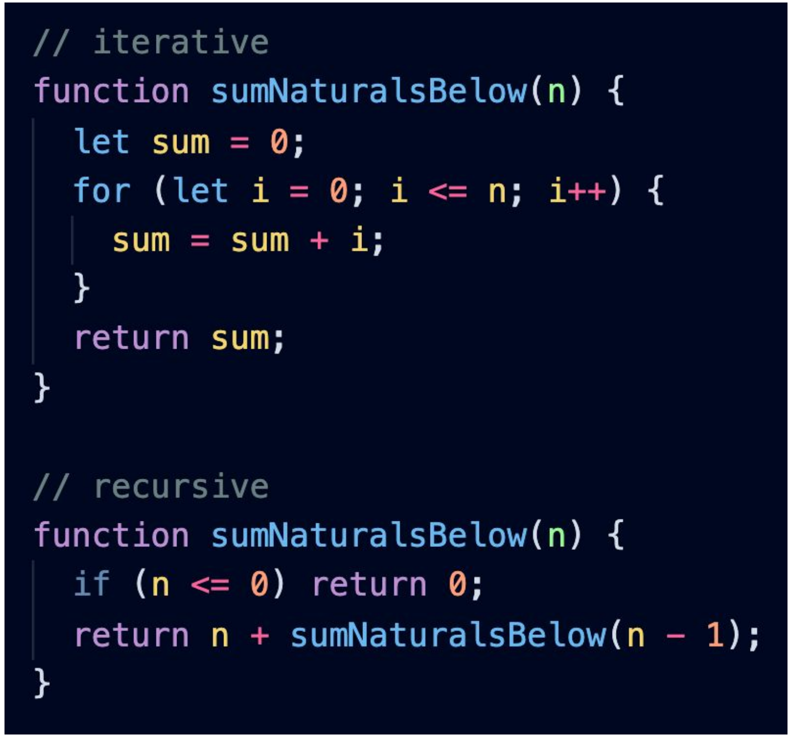
Recursion, like a for/while loop, requires terminating conditions



```
// Terminating function
function sumNaturalsBelow(n){
  if (n <= 0) return 0;
  return n + sumNaturalsBelow(n - 1);
}
```

Common Traits - Iterative/Recursive

- Initialized Value
- Changing Initial Value
- Terminating Condition



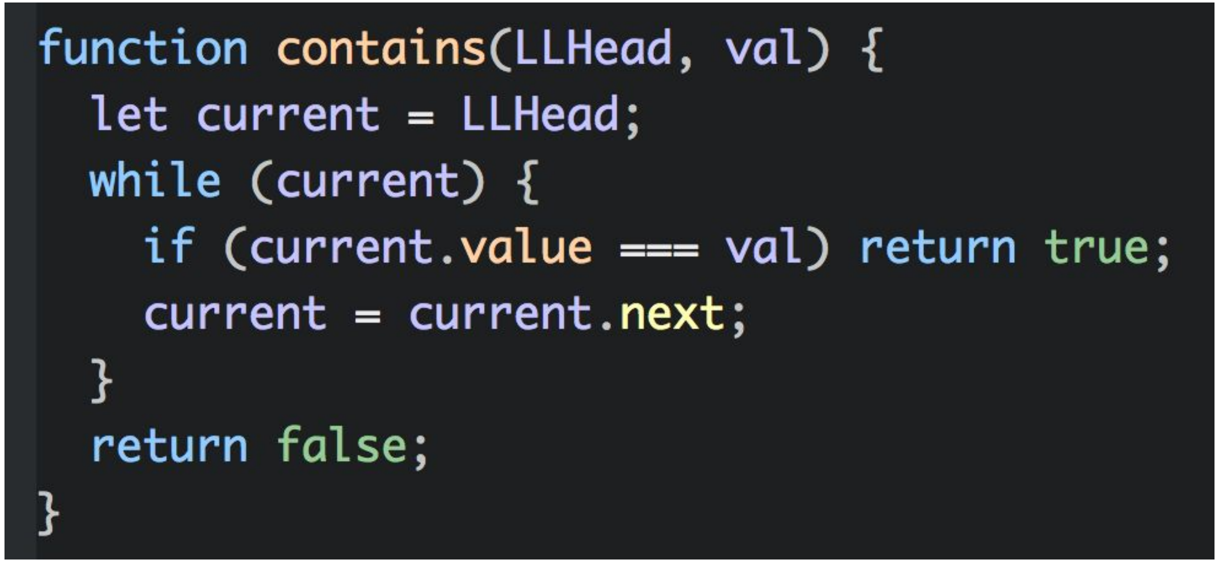
```
// iterative
function sumNaturalsBelow(n) {
  let sum = 0;
  for (let i = 0; i <= n; i++) {
    sum = sum + i;
  }
  return sum;
}

// recursive
function sumNaturalsBelow(n) {
  if (n <= 0) return 0;
  return n + sumNaturalsBelow(n - 1);
}
```

Why use recursion?

Recursive functions are frequently more readable, maintainable, and easier to understand

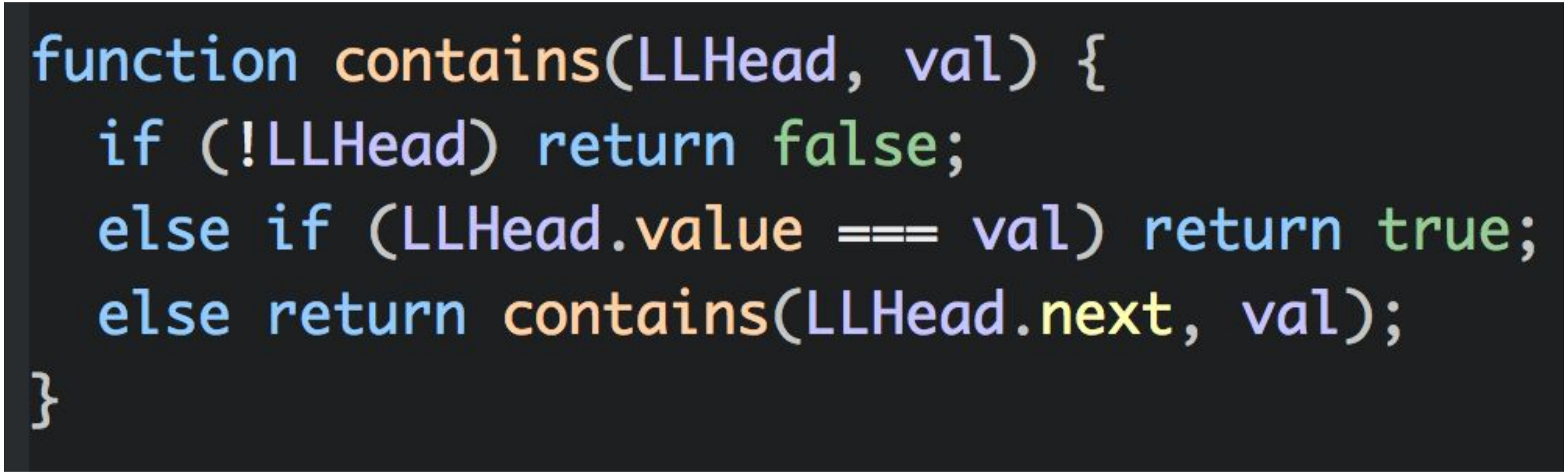
Without Recursion



```
function contains(LLHead, val) {
  let current = LLHead;
  while (current) {
    if (current.value === val) return true;
    current = current.next;
  }
  return false;
}
```

Recursive functions are frequently more readable, maintainable, and easier to understand

With Recursion



```
function contains(LLHead, val) {
  if (!LLHead) return false;
  else if (LLHead.value === val) return true;
  else return contains(LLHead.next, val);
}
```

Why are recursive algorithms easier to understand?

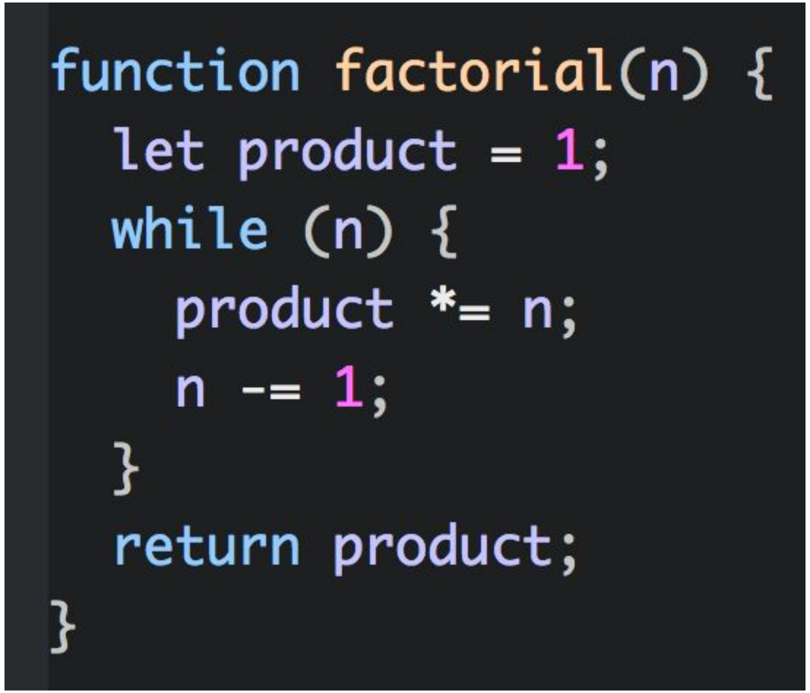
- Non-recursive functions tend to describe **how** to get to a solution.
- Recursive solutions describe **what** the solution is.
- Writing recursive functions often forces you to write **declarative** code instead of **imperative** code

Types of Recursion

Let's Compare Three ways to write a factorial algorithm

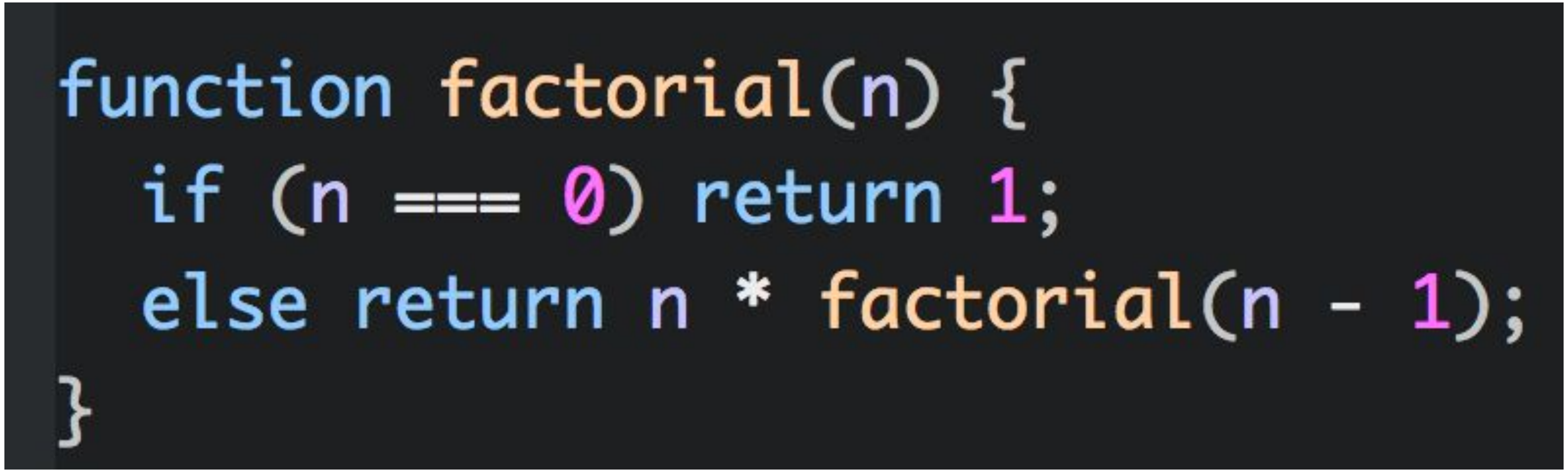
factorial(6) ==> 6 * 5 * 4 * 3 * 2 * 1

Factorial: Option #1



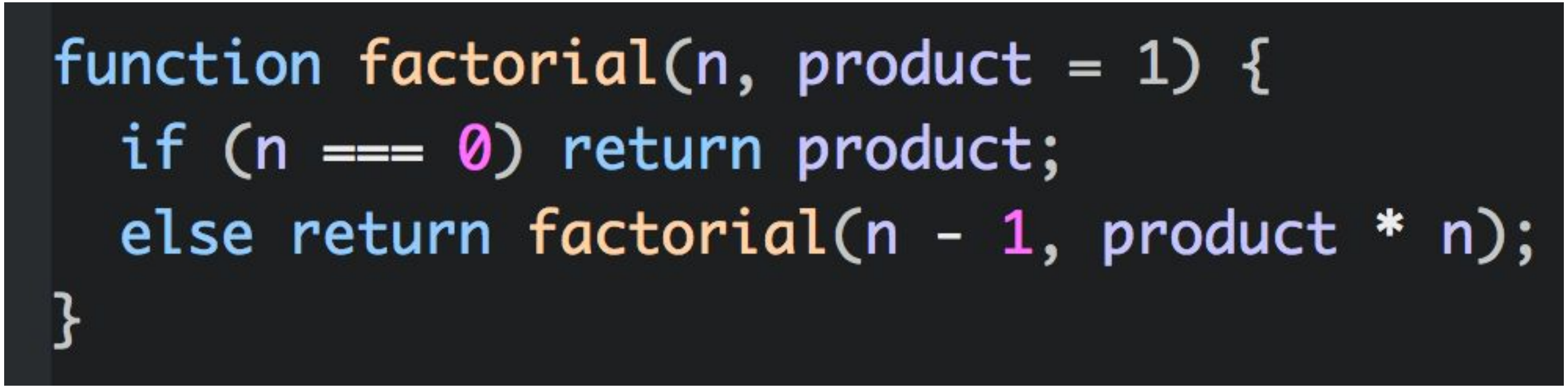
```
function factorial(n) {
  let product = 1;
  while (n) {
    product *= n;
    n -= 1;
  }
  return product;
}
```

Factorial: Option #2



```
function factorial(n) {
  if (n === 0) return 1;
  else return n * factorial(n - 1);
}
```

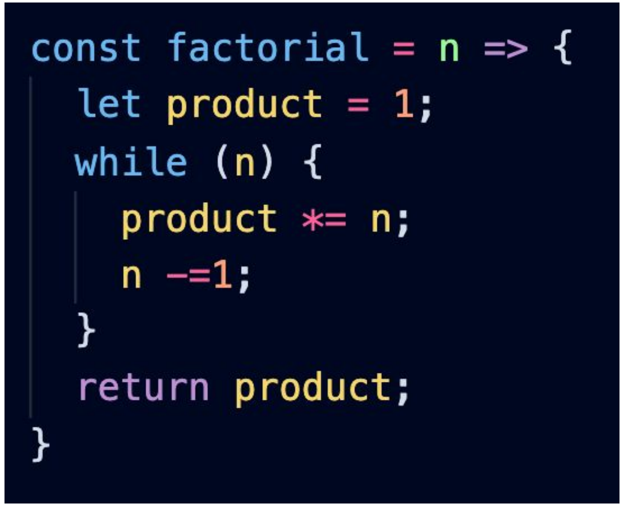
Factorial: Option #3



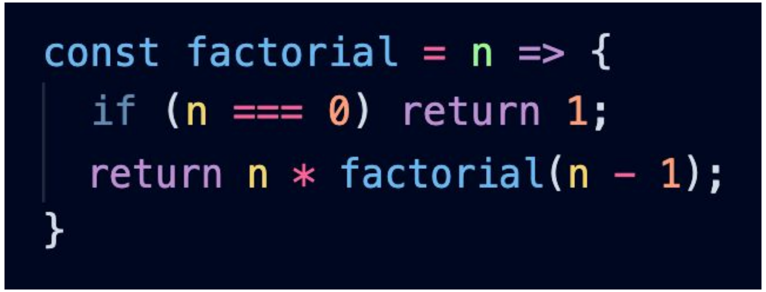
```
function factorial(n, product = 1) {
  if (n === 0) return product;
  else return factorial(n - 1, product * n);
}
```

Let’s Compare!

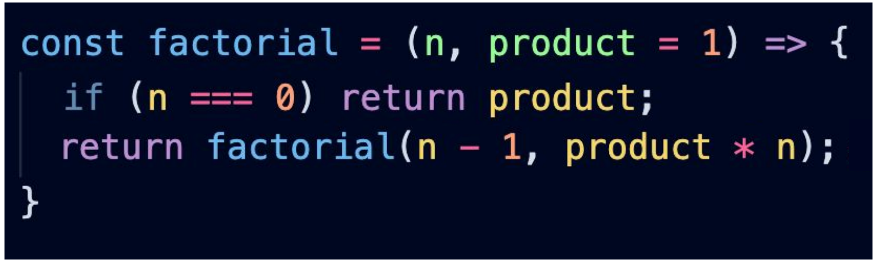
- *How is option #1 different from option #2 and #3?*



```
const factorial = n => {
  let product = 1;
  while (n) {
    product *= n;
    n -=1;
  }
  return product;
}
```



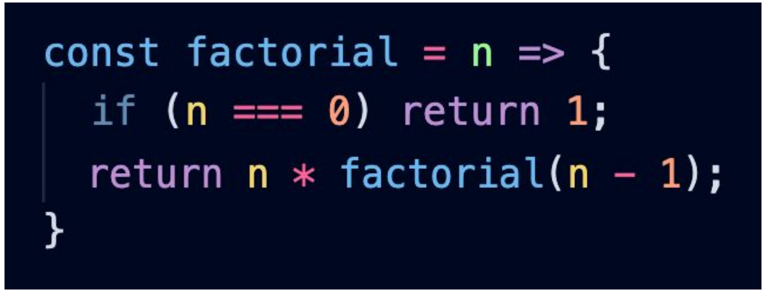
```
const factorial = n => {
  if (n === 0) return 1;
  return n * factorial(n - 1);
}
```



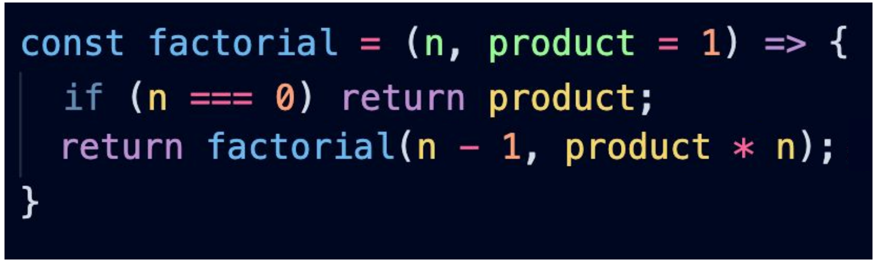
```
const factorial = (n, product = 1) => {
  if (n === 0) return product;
  return factorial(n - 1, product * n);
}
```

Let’s Compare!

- *How are option #2 and #3 similar? Different?*



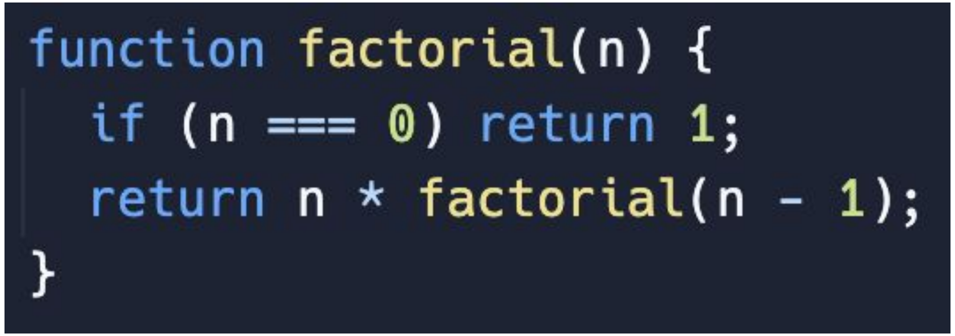
```
const factorial = n => {
  if (n === 0) return 1;
  return n * factorial(n - 1);
}
```



```
const factorial = (n, product = 1) => {
  if (n === 0) return product;
  return factorial(n - 1, product * n);
}
```

Linear Recursion:

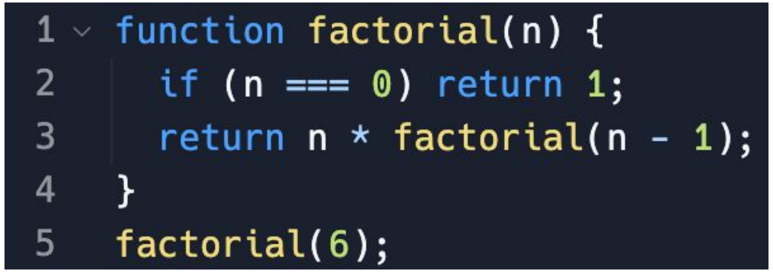
```
(factorial 6)
( * 6 (factorial 5) )
( * 6 ( * 5 (factorial 4) ) )
( * 6 ( * 5 ( * 4 (factorial 3) ) ) )
( * 6 ( * 5 ( * 4 ( * 3 (factorial 2) ) ) ) )
( * 6 ( * 5 ( * 4 ( * 3 ( * 2 (factorial 1) ) ) ) ) )
( * 6 ( * 5 ( * 4 ( * 3 ( * 2 ( * 1 (factorial 0) ) ) ) ) ) )
( * 6 ( * 5 ( * 4 ( * 3 ( * 2 ( * 1 * 1 ) ) ) ) ) )
( * 6 ( * 5 ( * 4 ( * 3 ( * 2 * 1 ) ) ) ) )
( * 6 ( * 5 ( * 4 ( * 3 * 2 ) ) ) )
( * 6 ( * 5 ( * 4 * 6 ) ) )
( * 6 ( * 5 * 24 ) )
( * 6 * 120 )
= 720
```



```
function factorial(n) {
  if (n === 0) return 1;
  return n * factorial(n - 1);
}
```

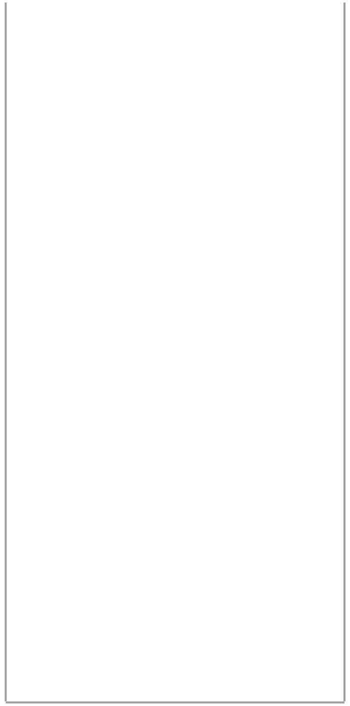
Time complexity: O(n)
Space complexity: O(n)

Linear Recursion:



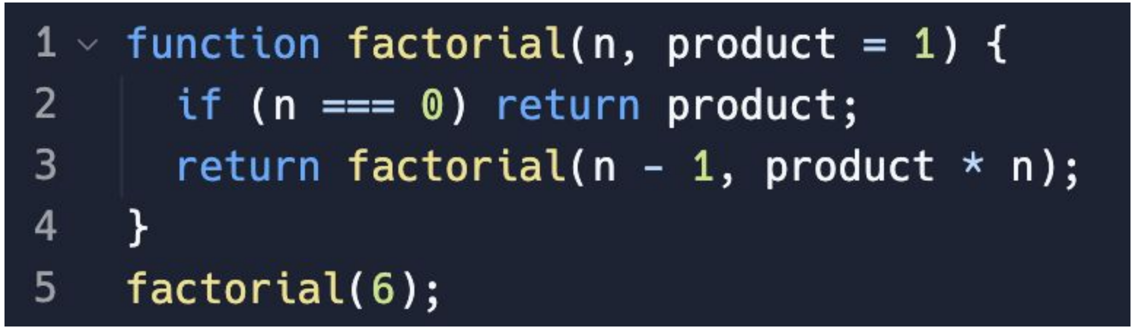
```
function factorial(n) {
  if (n === 0) return 1;
  return n * factorial(n - 1);
}
factorial(6);
```

Time complexity: O(n)
Space complexity: O(n)



Iterative Recursion (a.k.a. tail call recursion):

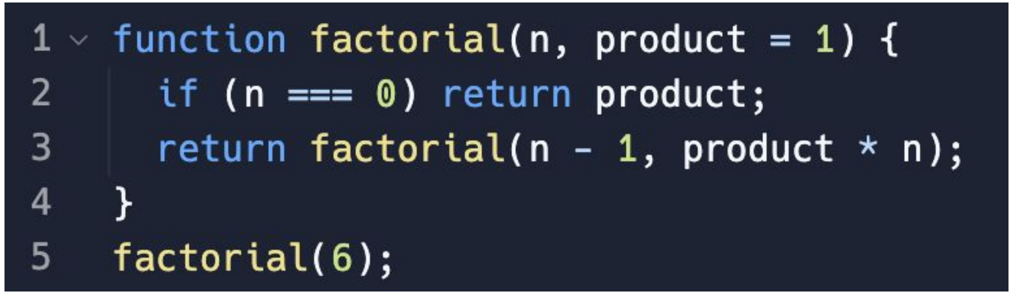
```
  (factorial 6)
⇒ (factorial 5, 6)
⇒ (factorial 4, 30)
⇒ (factorial 3, 120)
⇒ (factorial 2, 360)
⇒ (factorial 1, 720)
⇒ (factorial 0, 720)
⇒ 720
```



```javascript
function factorial(n, product = 1) {
  if (n === 0) return product;
  return factorial(n - 1, product * n);
}
factorial(6);
```

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

Iterative Recursion (a.k.a. tail call recursion):

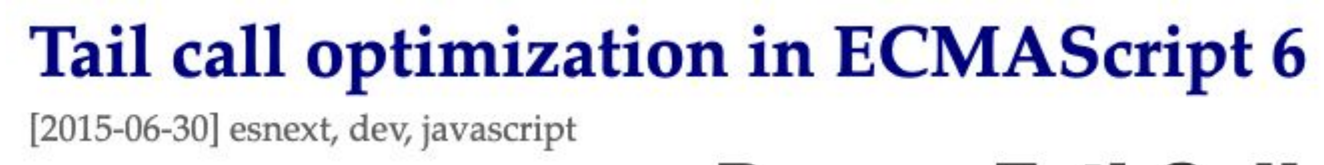


```
function factorial(n, product = 1) {
  if (n === 0) return product;
  return factorial(n - 1, product * n);
}
factorial(6);
```

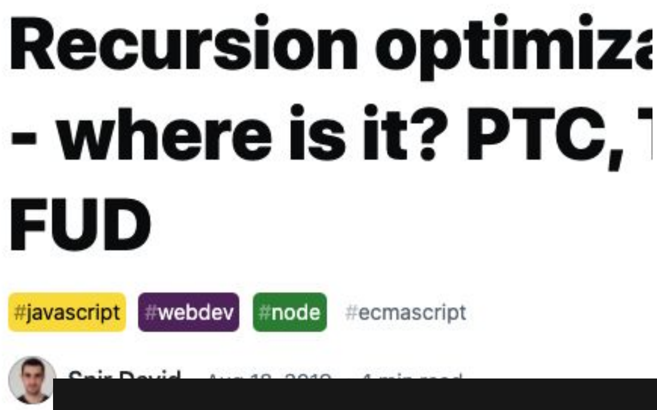
Time complexity: O(n)
Space complexity: O(1)

CALLSTACK

ES6 support for TCO

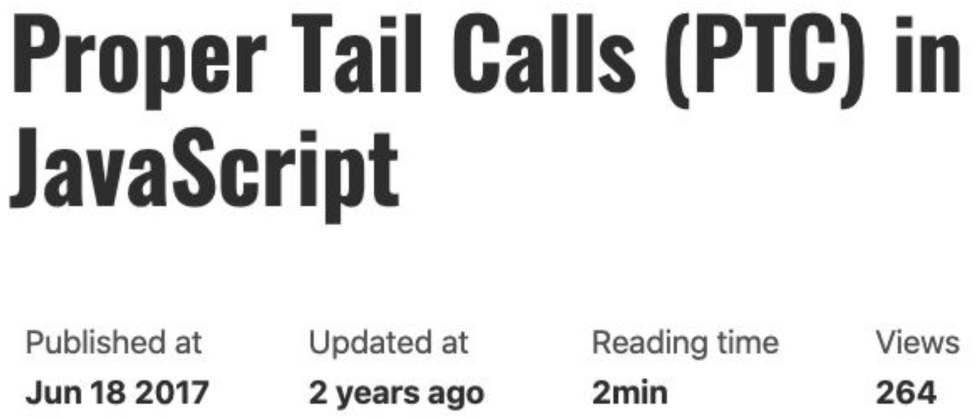

Tail call optimization in ECMAScript 6

[2015-06-30] esnext, dev, javascript


Recursion optimiza
- where is it? PTC, T
FUD

#javascript #webdev #node #ecmascript

Snir David


Proper Tail Calls (PTC) in JavaScript

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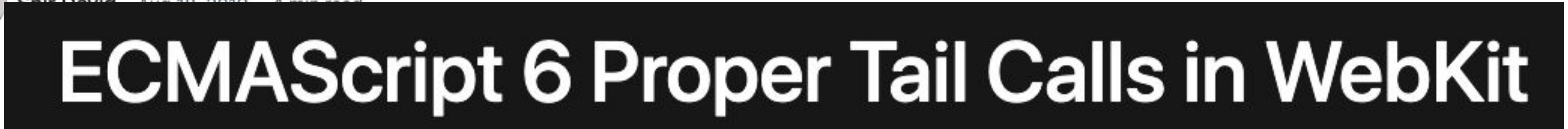
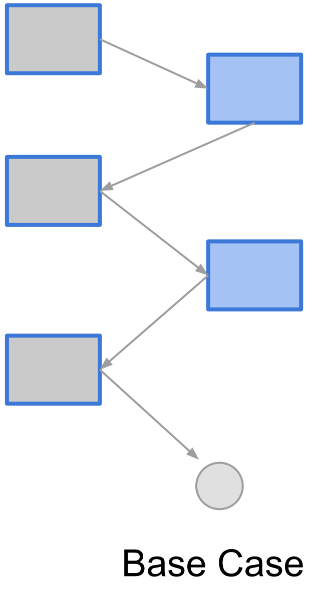
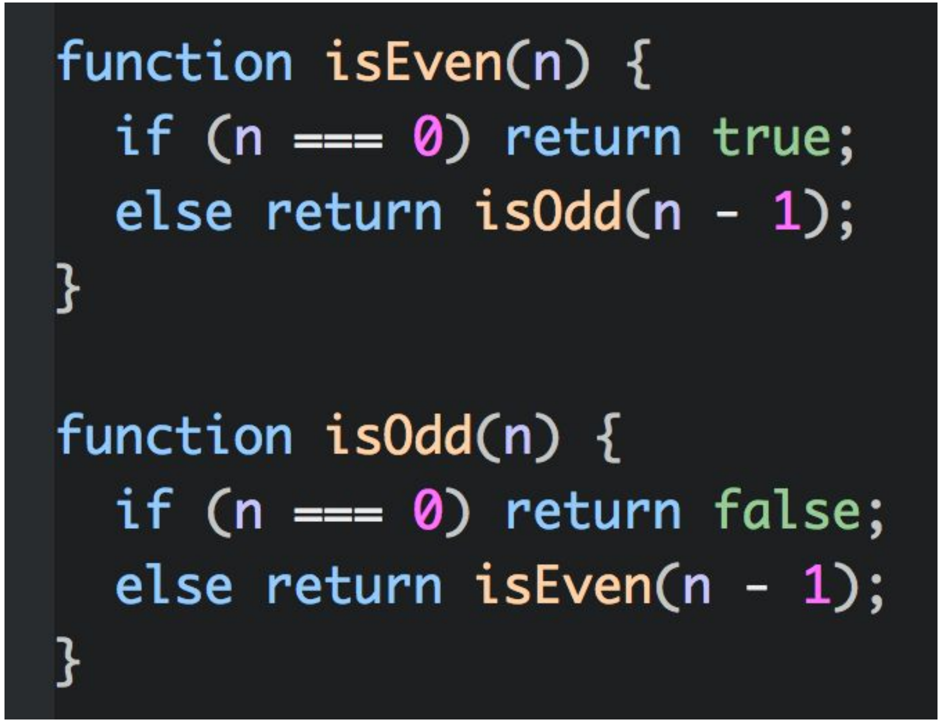

ECMAScript 6 Proper Tail Calls in WebKit

Other types of recursion: Mutual Recursion





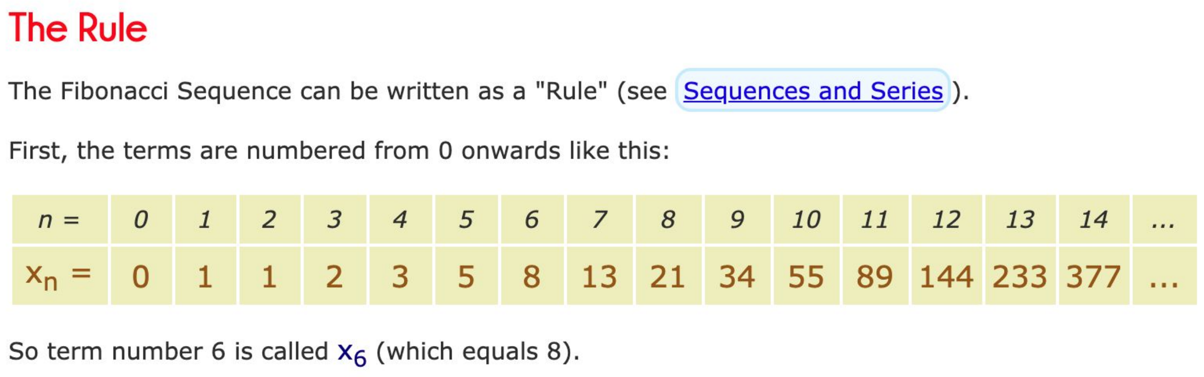
```
function isEven(n) {
  if (n === 0) return true;
  else return isOdd(n - 1);
}

function isOdd(n) {
  if (n === 0) return false;
  else return isEven(n - 1);
}
```

Other types of recursion: Mutual Recursion

JSON Parser!

Other types of recursion: Tree recursion (a.k.a multiple recursion)

Fibonacci numbers: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34...



The Rule

The Fibonacci Sequence can be written as a "Rule" (see Sequences and Series).

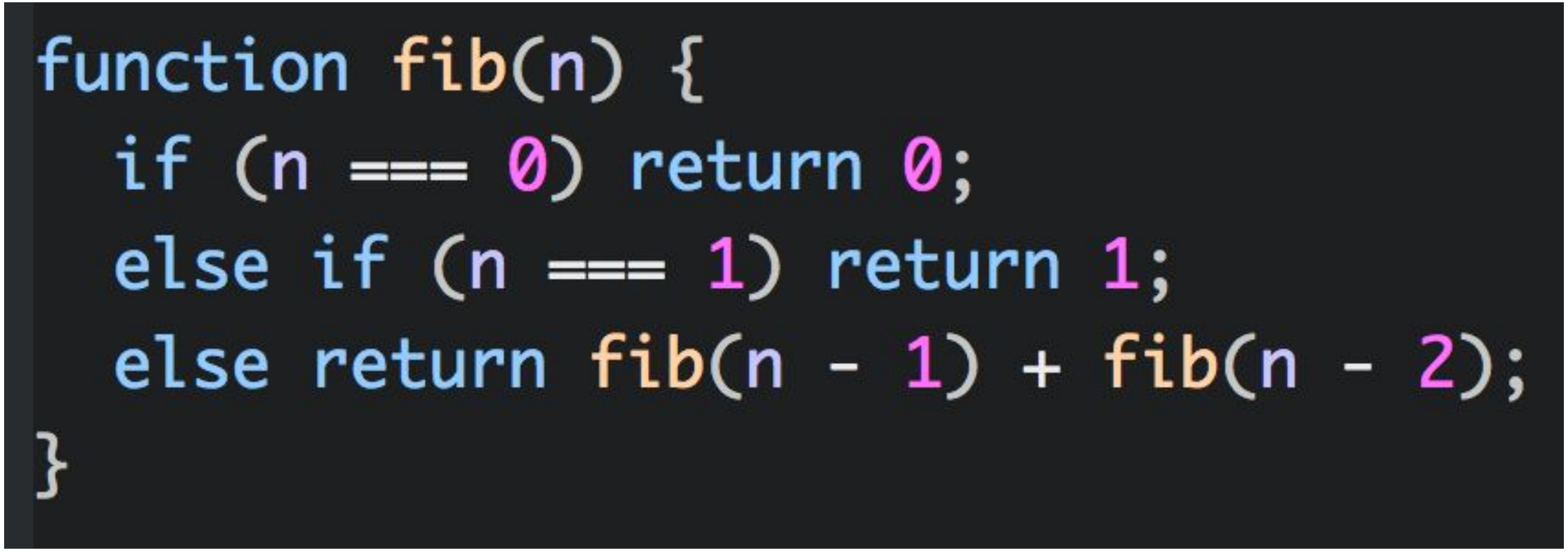
First, the terms are numbered from 0 onwards like this:

$n =$	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	...
$x_n =$	0	1	1	2	3	5	8	13	21	34	55	89	144	233	377	...

So term number 6 is called x_6 (which equals 8).

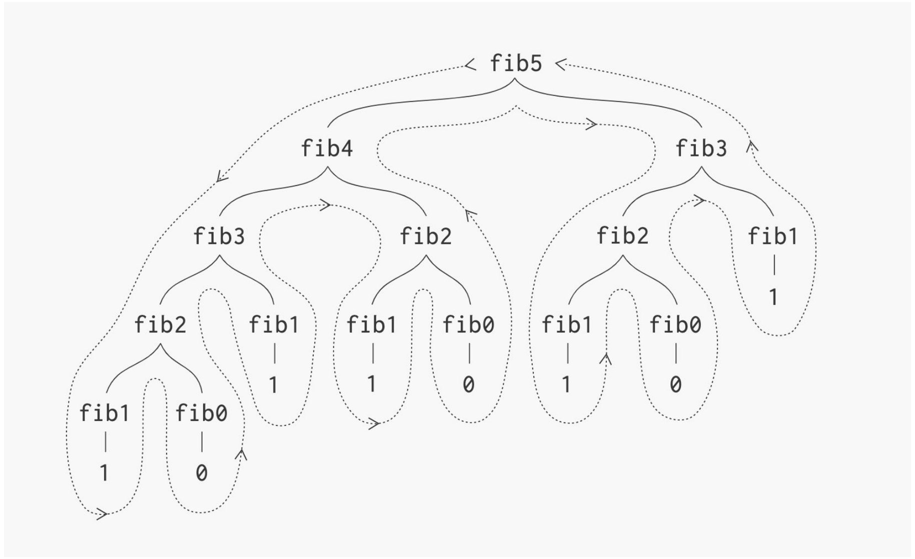
Other types of recursion: Tree recursion (a.k.a multiple recursion)

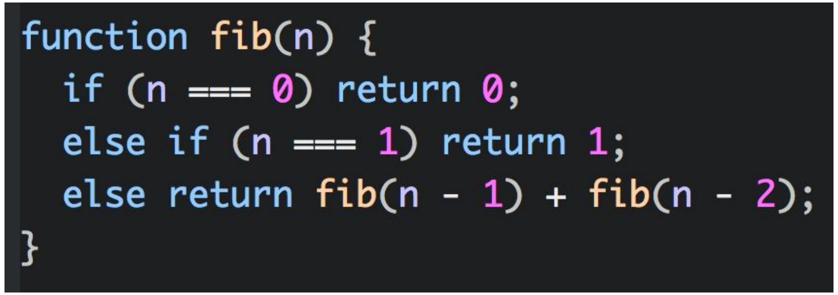
Finding the corresponding Fibonacci number at the nth term



```
function fib(n) {
  if (n === 0) return 0;
  else if (n === 1) return 1;
  else return fib(n - 1) + fib(n - 2);
}
```

Other types of recursion: Tree recursion (a.k.a multiple recursion)





```
function fib(n) {
  if (n === 0) return 0;
  else if (n === 1) return 1;
  else return fib(n - 1) + fib(n - 2);
}
```

Finding the corresponding Fibonacci number at the nth term

Summary

- A function is recursive if it calls itself in its own definition.
- Recursion allows us to write **declarative** code, rather than **imperative** code.
- Not all browsers implement Tail Call Optimization (TCO)
- Types of recursion:
  - Linear recursion
  - Tail recursion
  - Mutual recursion
  - Tree recursion

Further Reading

- Recursion in functional JavaScript (SitePoint)
- Recursion (JavaScript) (Microsoft)