Lecture 3: JavaScript - Functions

CPEN400A - Building Modern Web Applications - Winter 2019-1

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Thursday September 26, 2019

Recap: Previous Lecture - 2A

- In JavaScript, everything is an object
  - Objects are simply hash-tables of key-value pairs
- Objects can be created using either constructor functions or Object.create
  - Possible to support inheritance through prototype
- Reflection is permitted on JavaScript Objects

Functions in JavaScript: Creation

Note about Functions

- Functions are one of the most powerful features in JavaScript, and it is here that JS really shines (for the most part)
- However, there are some important differences between functions in JS and other imperative languages, such as Java
  - We'll touch upon some of these differences here

Important Differences with Java

- In JavaScript, functions are (Data) objects
  - Can be assigned to variables and invoked
  - Can be properties of an object (methods)
  - Can be passed around to other functions
- Functions can be nested inside other functions
  - Can be used to create what are known as closures
- Functions can be called with fewer or more arguments than they take in their parameter lists
  - Can be used to create curried functions

Creating a Standalone Function


```
var add = function ( a, b ) {
    return a + b;
}
```

Variable to which function is assigned

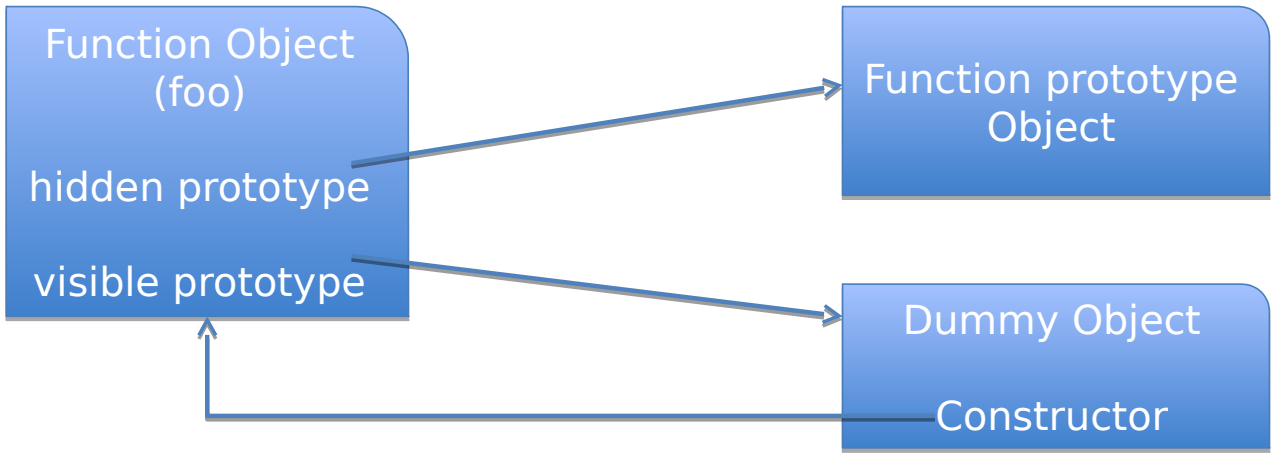
Function has no name – anonymous. Can specify name.

Parameters of the function – set to arguments passed in, undefined if none

Functions are Objects too !

- Every function is an instance of a Function object, which is itself derived from Object
- A function object has two prototype fields:
  - A hidden prototype field to Function.prototype, which in turn links to Object.prototype
  - A visible prototype field (Function.prototype) which points to an Object whose constructor function points to the function itself !

What's really going on ?



- Why is it done in this convoluted way ?

Reason: Constructors

- In JavaScript, Functions can be used as constructors for Object creation (new operator)
  - However, JS engine does not know ahead of time which functions are constructors and which aren't
  - For the constructor functions, the (visible) prototype is copied to the new object's prototype
  - New object's prototype's constructor is thus set to the constructor function that created the object

Example


```
1  function Point( x, y) {
2        this.x = x; this.y = y;
3
4  };
5
6
7  var p1 = new Point(2,3);
8  var p2 = new Point(5,7);
9
10 console.log(Object.getPrototypeOf(p1) == Object.
       getPrototypeOf(p2));
11 console.log(Object.getPrototypeOf(p1).constructor);
```

Methods

- Functions can be properties of an Object
  - Analoguous to methods in classical languages
  - Need to explicitely reference this in their bodies

```
1  this.dist = function(point) {
2
3     return Math.sqrt( (this.x - point.x)
4                     * (this.x - point.x)
5                     + (this.y - point.y)
6                     * (this.y - point.y) );
7     }
```

NOTE

this is bound to the object on which it is invoked

Adding Functions to Prototype

- Functions can also be added to the Prototype object of an object
  - These will be applied to all instances of the object
  - Can be overridden by individual objects if needed

```
1  Point.prototype.toString = function( ) {
2          return "(" + this.x + " , " + this.y + ")";
3  }
```

Invoking a Function

Invoking Functions

- There are four ways to invoke functions in JS
  1. Method calls (for functions in Objects)
  2. Standalone function (using function name)
  3. Constructors (creating object instances)
  4. Using Function.apply or Function.call
- Each of these methods has different bindings of the this parameter

1) Method call (over an object)

- object.methodName(parameters)
- Example: p1.dist (p2);

NOTE

this is bound to the object on which it is called. In the example, this = p1. This binding occurs at invocation time (late binding).

2) Calling a standalone function

- If the function is a Standalone one, then the object is called with the *global* context as this
  - Can lead to some strange situations (later)
  - A mistake in the language according to Crockford !

```
1  var add = function( p1, p2) {
2      return new Point(p1.x + p2.x, p1.y + p2.y);
3  }
4
5  add( p1, p2 );
```

3) Constructors

- Using the new operator as we've seen
- this is set to the new object that was created
  - Automatically returned unless the constructor chooses to return another object (non-primitive)
- Bad things can happen if you forget the new before the call to the constructor (Why ?)

4) *Function.apply*

- Most general way to call a function
  - Can set this to any arbitrary object in program
  - Can emulate the other three ways of invocation
  - Can also use call with the arguments specified
    - apply more generic than call (i.e., can support variadic arguments). See later for call

4) *Function.apply*


```
1  var add2 = function( point1, point2 ) {
2          var p = Object.create(this);
3          p.x = point1.x + point2.x;
4          p.y = point1.y + point2.y;
5          return p;
6  }
7
8  var Points = [ p1, p2 ];
9  var p = add2.apply( Object.getPrototypeOf(p1),  Points);
10 document.writeln(p);
```

4) *Function.call*

- call is similar to apply except that the arguments are specified directly as part of the function parameters rather than in an array
- We used call before for calling the super-class's constructor (for inheritance)

```
1  var p = add2.call( Object.getPrototypeOf(p1),  p1, p2);
2  document.writeln(p);
```

Class Activity

- Emulate the new operator through a function new using Object.create and Function.apply. Add this method to the Point constructor function and not to the Point's prototype. This should not duplicate the object's constructor's code, but invoke it.
- You can access arguments of a function in the array arguments from within the function (variadic arguments - see later in this presentation).
- To call this function, you'd write code like:

```
1  var p1 = Point.new(2, 5);
2  var p2 = Point.new(3, 7);
```

Arguments and Exceptions

Arguments

- JavaScript does not enforce any rules about function parameters matching their arguments in number (or type for that matter)
- Any additional arguments are simply disregarded (unless function accesses them)
- Fewer arguments mean the remaining parameters are set to undefined

Variadic Functions

- Functions can access their arguments using the *arguments* array
- Excess parameters are also stored in the array

```
1  var addAll = function( ) {
2          var p = new Point(0,0);
3          for (var i=0; i<arguments.length; i++) {
4                  var point = arguments[i];
5                  p.x = p.x + point.x;
6                  p.y = p.y + point.y;
7          }
8          return p;
9  }
```

Return Values

- Functions can return anything they like
  - Objects, including other functions (for closures)
  - Primitive types including null
- If the function returns nothing, it's default return value becomes *undefined*
- The only exception is if it's a constructor
  - Returning object will cause the new object to be lost !

Exceptions

- Functions may also throw exceptions
  - Exception can be any object, but it's customary to have an exception name and an error message
  - Other fields may be added based on context
- Exceptions are caught using try. . . catch
  - Single catch block for the try
  - Catch can do whatever it wants with the exception, including throwing it again

Exception: Example


```
1  var addAll = function( ) {
2     var p = new Point(0,0);
3     for (var i=0; i<arguments.length; i++) {
4        var  point = arguments[i];
5        if ( point.x==undefined || point.y==undefined )
6           throw { name: TypeError,
7              message: "Object " + point + " is not of type
                   Point"
8        };
9          p.x = p.x + point.x;
10         p.y = p.y + point.y;
11     }
12     return p;
13 }
```

Class Activity

- Modify the addAll code to make sure you return the sum so far if the exception is thrown, i.e., sum of elements till the faulty element (you may modify the exception object as you see fit).

Note

By *return*, we mean that the *caller* will have access to the sum up until the faulty element

- Write code to invoke the addAll function correctly, and to handle the exception appropriately.

Nested Functions and Closures

Nested Functions: Closures

- In JavaScript, functions can nest inside other functions, unlike in languages like Java
- Nested functions can access their enclosing function's properties (this is a good thing)
- However, nested functions cannot access the parent function's this and arguments!

Closures

- A closure is a nested function that "remembers" the value of it's enclosing function's variables
- Can be used for implementing simple, stateful objects
  - Allow variables to be hidden from other objects
  - Can allow objects to be constructed in parts

Closures: Example


```
1  function Adder(val) {
2     var value = val;
3
4     return function(inc) {
5                         // Returns a function that needs
6                         // to be invoked to get it to
7                         // perform the operation
8
9        value = value + inc;
10                        // Can access parent function
11                        // (Adder)'s local variable
12
13       return value;
14    }
15 };
16
17 var f = Adder(5);
18 document.writeln( f(3) ); // Prints 8
19 document.writeln( f(2) ); // Prints 10
```

Another Example of Closures


```
1  function Counter( initial ) {
2      var val = initial;
3      return {
4          increment: function() { val += 1; },
5          reset: function() { val = initial; },
6          get: function() { return val; }
7      }
8  };
9
10 var f = Counter(5), g = Counter(10);
11 f.increment();  f.reset(); f.increment();
12 g.increment(); g.increment();
13 console.log( f.get() + " , " + g.get() );
```

Why closures are useful ?

- Allow you to remember state in Web Applications
  - Especially when you have many different handlers construct parts of an object (e.g., AJAX messages)
  - Very useful for callbacks in JavaScript: return the callback function from the parent function
  - Way to emulate private variables (JS has none)
- Closures are extensively used in frameworks such as **jQuery** to protect the integrity of internal state

Closures: Referencing Parent Object

- In a closure, what does *this* refer to ?
  - The nested function scope
- But what if you wanted to access the parent function's context (e.g., to invoke a method) ?
  - You no longer get access to parent's *this*
  - Store the parent context in a local variable *that*
- Caution: Can lead to high memory consumption

Another example...


```
1  // Implements a closure with multiple counters
2  function MultiCounter( initial ) {
3     var val = [];      //  Empty array of counter values
4     var init = function() {
5        /* Initialize the values of  val from the initial
             array */
6        val = [];
7        for (var i=0; i<initial.length; i++)
8           val.push( initial[i] );
9     };
10    init();
11    return {
12       increment: function(i) { val[i] += 1; },
13       resetAll: function() { init(); },
14       getValues: function() { return val; }
15    }
16 };
17 var m = MultiCounter( [1, 2, 3] );
```

Class Activity- 1


```
1  /* 1) What happens when you execute the following code ? Why
        does it not work as you probably intended ? */
2
3  var MakeCounters = function(n) {
4      var counters = [];
5      for (var i=0; i<n; i++) {
6          var val = i;
7          counters[i] = {
8              increment: function() { val++; },
9              get: function() { return val; },
10             reset: function() { val = i; }
11         }
12     }
13     return counters;
14 }
15 var m = MakeCounters(10);
16 for (var i=0; i<10; i++) {
17     document.writeln("Counter[ " + i + "] = " + m[i].get());
18 }
```

Class Activity- 2


```
1  /* 2) How would you change the code to maintain an array of
       counters the right way (with distinct values from 1 to n
       )? (same code below) */
2
3  var MakeCounters = function(n) {
4     var counters = [];
5     for (var i=0; i<n; i++) {
6        var val = i;
7        counters[i] = {
8           increment: function() { val++; },
9           get: function() { return val; },
10          reset: function() { val = i; }
11       }
12    }
13    return counters;
14 }
15 var m = MakeCounters(10);
16 for (var i=0; i<10; i++) {
17    document.writeln("Counter[ " + i + "] = " + m[i].get());
18 }
```

Class Activity- 2 - solution and 3 - optimization


```
1  /* 3) In class activity 2, did you end up adding additional
       fields to counters? If so, then can you come up with a
       different solution without such additional fields?
2     Why do we need the "this" keyword?*/
3
4  var MakeCounters = function(n) {
5     var counters = [];
6     for (var i=0; i<n; i++) {
7        counters[i] = {
8           val : i,
9           initial : i,
10          increment: function() { this.val++; },
11          get: function() { return this.val; },
12          reset: function() { this.val = this.initial; }
13       }
14    }
15    return counters;
16 }
17 var m = MakeCounters(10);
18 for (var i=0; i<10; i++) {
19    document.writeln("Counter[ " + i + "] = " + m[i].get());
20 }
```

Class Activity- 3 - solution


```
1  /* 4) What's the advantage of this solution compared to the
       previous one?
2     Why don't we need the "this" keyword?*/
3
4  var MakeCounters = function(n) {
5     var counters = [];
6     for (var i=0; i<n; i++) {
7        counters[i] = function( ) {
8           var initial = i, val = initial;
9           return {
10             increment: function() { val++; },
11             get: function() { return val; },
12             reset: function() { val = initial; }
13          }
14       }();  // Why do we need the parentheses () ?
15    }
16    return counters;
17 }
18 var m = MakeCounters(10);
19 for (var i=0; i<10; i++) {
20    document.writeln("Counter[ " + i + "] = " + m[i].get());
21 }
```

Gotchas with Closures

- Remember, the closure stores a link to the variables of the original function, not a copy
  - Any changes to the enclosing variable are reflected in the closure, even after it was created
- Keep the amount of state you want to save in the closure to the minimum necessary state
  - Otherwise, garbage collector cannot release it and you will get memory leaks, and run out of memory

Higher-Order Functions and Currying

High-Order Functions

- Passing functions as arguments to other functions to perform some task
  - No need to wrap the function in some weird object as C++ or Java require
  - Function can take any arguments – use apply as seen previously
- This is very useful for creating generic objects that have 'plug-and-play' functionality
- Can also return functions in JS, as we've just seen

Higher Order Function: Example - 1


```
1  var map = function( array, fn ) {
2      // Applies fn to each element of list, returns a new list
3      var result = [];
4      for (var i = 0; i < array.length; i++) {
5          var element = array[i];
6          result.push( fn(element) );
7      }
8      return result;
9  }
10
11 map( [3, 1, 5, 7, 2], function(num) { return num + 10; } );
```

Currying

- Currying: binding some arguments of a function, so that only the remaining arguments need to be filled in
  - Use function.bind to bind some arguments
- Very useful when used in combination with higher-order functions for specifying arguments of functions being passed in

Example of using bind

- Assume that you have a function called foo that takes two arguments
  - function foo(a, b) { . . . }
- You can bind the first argument to a constant value (or anything else) to return a function goo that takes a single argument as follows.
  - var goo = foo.bind(null, <value>);
  - null specifies the calling context to bind to

Using currying

- Now you can pass the bound function to the map higher-order function we defined earlier.

```
1  function add(a, b) { return a + b; }
2  var add10 = add.bind(null, 10);
3  // add10 takes a single argument and adds 10 to
4  // it as the other argument is bound to the value 10
5  map( [1, 3, 5, 2, 10, 11], add10 );
```

Class Activity - 1

Class Activity - 1

- Write an implementation of *filter* using JavaScript. *filter* takes 2 parameters, an array *arr* and a function *f* that takes a single parameter and returns true or false. It then creates another array with only the elements in *arr* for which f returns true.

Class Activity - 2

- Consider a function lesserThan that compares two numbers and returns true if the first number is smaller than the second number. Create a curried version of this function to pass to the *filter* function with the first argument set to a user-specified threshold.
- What's the effect of the filter operation here ?

Class Activity: Solution


```
1  var filter = function( array, fn ) {
2      var result = [];
3      for (var i = 0; i < array.length; i++) {
4          var element = array[i];
5          if (fn(element) ) result.push(element);
6      }
7      return result;
8  };
9
10 var lesserThan = function(a, b) { return (a < b) ? true:
       false; };
11 var greaterThan5 = lesserThan.bind(null, 5);
12
13 var a = [ 1, 3, 10, 8, 2, 7, 6 ];
14 var c = filter( a, greaterThan5);
15 console.log(c);
```

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