Lecture 2: JavaScript - Objects and Prototypes

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Javascript: History and Philosophy

Javascript: History

- Invented in 10 days by Brendan Eich at Nescape in May 1995 as part of the Navigator 2.0 browser
  - Based on Self, but dressed up to look like Java
  - Standardized by committee in 2000 as ECMAScript

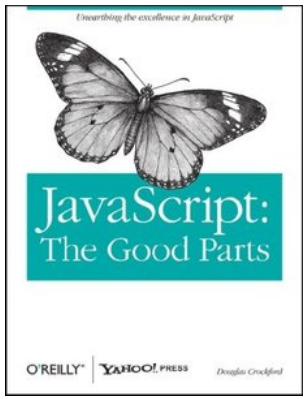
Brendan Eich (Inventor of JavaScript):

*JavaScript (JS) had to "look like Java" only less so, be Java's dumb kid brother or boy-hostage sidekick. Plus, I had to be done **in ten days** or something worse than JS would have happened*

Javascript: Philosophy

- Everything is an object
  - Includes functions, non-primitive types etc.
  - Even the class of an object is an object !
- Nothing has a type
  - Or its type is what you want it to be (duck typing)
  - No compile-time checking (unless in strict mode)
  - Runtime type errors can occur
- Programmers make mistakes anyways
  - If an exception is thrown, do not terminate program (artifact of browsers, rather than JS)
- Code is no different from data
  - So we can use 'eval' to convert data to code
- Function's can be called with fewer or more arguments than needed (variadic functions)

JavaScript: "Good" or "Evil" ?



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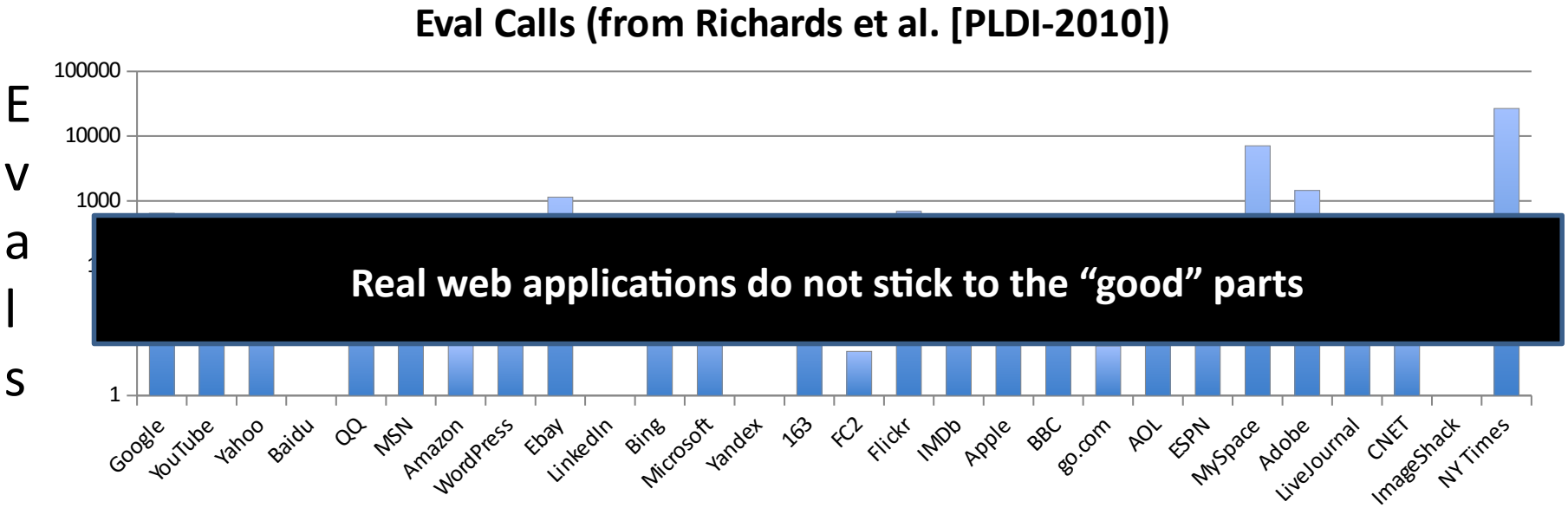

Philosophy of our course

- We'll try and use the good subset of JavaScript as far as possible as in Doug Crockford's book
- However, we'll also learn about the "evil" features of JS so that we can recognize them
  - Sometimes there is a good reason for using an evil feature (e.g., eval is an elegant way to parse JSON)
  - Sometimes you have to deal with legacy code or code written by others who may use these features

Object Creation in Javascript

What is an Object in JS ?

- Container of properties, where each property has a name and a value, and is mutable
  - Property names can be any string, including the empty string
  - Property values can be anything except undefined
- What are not objects ?
  - Primitive types such as numbers, booleans, strings
  - null and undefined – these are special types

What about classes ?

- There are no classes in JavaScript, as we understand them in languages such as Java
- "What ? How can we have objects without classes ?"
  - Objects use what are known as prototypes
  - An object can inherit the properties of another object using prototype linkage (more later)

Example of Object Creation


```
1  // Initializing an empty object
2  var empty_object = {};
3
4  // Object with two attributes
5  var name = {
6      firstName: "Karthik",
7      lastName: "Pattabiraman";
8  };
```

NOTE

You don't need a quote around firstName and lastName as they're valid JavaScript identifiers

Retrieving an Object's Property


```
1  name["firstName"]
2  // Equivalent to:
3  name.firstName
4
5  name["lastName"]
6  // Equivalent to:
7  name.lastName
```

- What if you write name["middleName"]?
  - Returns undefined. Later use of this value will result in an "TypeError" exception being thrown

Update of an Object's Property


```
1  name["firstName"] = "Different firstName";
2  name.lastName = "Different lastName";
```

- What happens if the property is not present ?
  - It'll get added to the object with the value
- In short, objects behave like hash tables in JS

Objects are passed by REFERENCE !

- In JavaScript, objects are passed by REFRENCE
  - No copies are ever made unless explicitly asked
    - i.e., JSON.parse(JSON.stringify(obj))
  - Changes made in one instance are instantly visible in all instances as it is by reference

Object Constructor and Methods

How to create an object ?

- Define the object type by writing a "Constructor function"
  - By convention, use a capital letter as first letter
  - Use "this" within function to initialize properties
- Call constructor function with the new operator and pass it the values to initialize
  - Forgetting the 'new' can have unexpected effects
- 'new' operator to create an object of instance 'Object', which is a global, unique JavaScript object

Object Creation using New

```
1  var Person = function(firstName, lastName, gender)
       {
2        this.firstName= firstName;
3        this.lastName = lastName;
4        this.gender = gender;
5  }
6  var p = new Person("John", "Smith", "Male");
```

this keyword

- It's a reference to the current object, and is valid only inside the object
- Need to explicitly use this to reference the object's fields and methods
  - Forgetting this means you'll create new local vars
  - Can be stored in ordinary local variables
  - Cannot be modified from within the object

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 (Later)

Object Methods

- Functions that are associated with an object
- Like any other field of the object and invoked as object.methodName()
  - Example: Polygon.draw(10, 100);
  - this is automatically defined inside the method
  - Must be explicitly added to the object

```
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

Calling a Method

- Simply say object.methodName(parameters)
- Example: p1.dist(p2);
- this is bound to the object on which it is called. In the example, this = p1. This binding occurs at invocation time (late binding).

Prototypes and Inheritance

Object Prototype

- Every object has a read-only field called [[Prototype]](__proto__)
  - [[Prototype]] is a pointer to the object the object is created from (i.e., the class object)
  - Changing the **prototype object** instantly changes all instances of the object
- The default prototype value for a given object is Object
  - Can be changed when using new or Object.create to construct the object

Object Prototype: Example

- In the previous example, what is the [[Prototype]] value of a "Person" object ?

```
1  var p = new Person("John", "Smith", "Male");
2  console.log( Object.getPrototypeOf(p) );
```

- What will happen if we do the following instead

```
1  console.log( Object.getPrototypeOf(Person) );
```

Prototype Field

- Prototypes of objects created through {} (object literal syntax) is
  - Object.prototype
- Prototype of objects created using new Object
  - Object.prototype
- Prototype of objects created using new and constructors functions (e.g., Person)
  - Prototype field set according to the constructor function (if object) (e.g., Person)
  - Object.prototype (otherwise)

What 'new' really does?

- Initializes a new native object
- Sets the object's [[Prototype]] field to the constructor function's prototype field
  - In Chrome (V8 engine), the prototype of an object instance o is accessible through the hidden property o.__proto__.
    - Direct usage should be avoided! Use instead Object.getPrototypeOf(o)
  - If it's not an Object, sets it to Object.prototype
    - i.e., Object.create(null)
- Calls the constructor function, with the object as this
  - Any fields initialized by the function are added to this
  - Returns the object created **if and only if** the constructor function returns a primitive type (i.e., number, boolean, etc.). Ideally, the constructor function shouldn't return anything!

Prototype Modification

- An object's prototype object is just another object (typically). So it can be modified too.
- We can add properties to prototype objects – the property becomes instantly visible in all instances of that prototype (even if they were created before the property was added)
  - Reflects in all descendant objects as well (later)

Prototype Modification: Example


```
1  var p1 = new Person("John", "Smith", "Male");
2
3  Person.prototype.print = function() {
4      console.log( "Person: " + this.firstName
5              + this.lastName + this.gender + "\n");
6  }
7
8  var p2 = new Person("Linda", "James", "Female");
9  p1.print();
10 p2.print();
```

Delegation with Prototypes

- When you lookup an Object's property, and the property is not defined in the Object,
  - It checks if the Object's prototype is a valid object
  - If so, it does the lookup on the prototype object
  - If it finds the property, it returns it
  - Otherwise, it recursively repeats the above process till it encounters Object.prototype
  - If it doesn't find the property even after all this, it returns undefined

Prototype Inheritance

- Due to Delegation, Prototypes can be used for (simulating) inheritance in JavaScript
  - Set the prototype field of the child object to that of the parent object
  - Any access to child object's properties will first check the child object (so it can over-ride them)
  - If it can't find the property in the child object, it looks up the parent object specified in prototype
  - This process carries on recursively till the top of the prototype chain is reached (Object.prototype)

Prototype Inheritance: Example


```
1  var Employee = function(firstName, lastName, Gender, title)
       {
2      Person.call( this, firstName, lastName, Gender );
3      this.title = title;
4  }
5
6  Employee.prototype = new Person();
7     /* Why should you create a new person object ? */
8
9  Employee.prototype.constructor = Employee;
10
11 var emp = new Employee("ABC", "XYZ", "Male", "Manager");
```

Object.create(proto)

- Creates a new object with the specified prototype object and properties
- proto parameter must be null or an object
  - Throws TypeError otherwise

Object.create Argument

- Can specify initialization parameters directly in Object.create as an (optional) 2nd argument

```
var e = Object.create( Person, { Title: {value: "Manager" }} )
```

- We can specify other elements such as enumerable, configurable etc. (more later)

Prototype Inheritance with *Object.create*: Example


```
1  var Person = {
2      firstName:  "John";
3      lastName: "Smith";
4      gender: "Male";
5      print : function() {
6          console.log( "Person : " + this.firstName
7                  + this.lastName + this.gender;
8      }
9  };
10 var e = Object.create( Person );
11 e.title = "Manager";
```

Design Tips

- Object.create might be cleaner in some situations, rather than using new and .prototype (no need for artificial objects)
- With new, you need to remember to use this and also NOT return an object in the constructor
  - Otherwise, bad things can happen
- Object.create allows you to create objects without running their constructor functions
  - Need to run your constructor manually if you want
  - i.e., Person.call(p2, "Bob")

Class Activity

- Construct a class hierarchy with the following properties using both pseudo-class inheritance (through constructors) and prototypal inheritance (thro' Object.create). Add an area method and a toString prototype function to all the objects.

Point { x, y } ⇒ Circle { x, y ,r } ⇒ Ellipse { x, y, r, r2 }

Type-Checking and Reflection

Reflection and Type-Checking

- In JS, you can query an object for its type, prototype, and properties at runtime
  - To get the Prototype: getPrototypeOf()
  - To get the type of: typeof
  - To check if it's of certain instance: instanceof
  - To check if it has a certain property: in
  - To check if it has a property, and the property was not inherited through the prototype chain: hasOwnProperty()

typeof

- Can be used for both primitive types and objects

```
1  typeof( Person.firstName ) => String
2  typeof( Person.lastName ) => String
3  typeof( Person.age ) => Number
4  typeof(Person.constructor) => function (prototype)
5  typeof(Person.toString) => function (from Object)
6  typeof(Person.middleName) => undefined
```

instanceof

- Checks if an object has in its prototype chain the prototype property of the constructor

```
object instanceof constructor => Boolean

// Example:
var p = new Person( /* ... */ );
var e = new Employee( /* ... */ );

p instanceof Person;     // True
p instanceof Employee;    // False
e instanceof Person;   // True
e instanceof Employee;    // True
p instanceof Object;     // True
e instanceof Object;     // True
```

getPrototypeOf

- Gets an object's prototype (From the prototype field) – Object.getPrototypeOf(Obj)
  - Equivalent of 'super' in languages like Java
- Notice the differences between invoking getPrototypeOf on an object constructed using the "associative array" syntax vs through a constructor!

```
1  var proto = {};
2  var obj = Object.create(proto);
3  Object.getPrototypeOf(obj);   // proto
4  Object.getPrototypeOf(proto); // Object
```

in operator

- Tests if an object o has property p
  - Checks both object and its prototype chain

```
1  var p = new Person( /* ... */ );
2  var e = new Employee( /* ... */ );
3
4  "firstName" in p;   // True
5  "lastName" in e;    // True
6  "Title" in p;    // False
```

hasOwnProperty

- Only checks the object's properties itself
  - Does not follow the prototype chain
  - Useful to know if an object has overridden a property or introduced a new one

```
1  var p = new Employee( /* ... */ );
2  p.hasOwnProperty("Title")  // True
3  p.hasOwnProperty("FirstName")  // True (why ?)
```

Iterating over an Object's fields

- Go over the fields of an object and perform some action(s) on them (e.g., print them)
  - Can use hasOwnProperty as a filter if needed

```
1  var name;
2  for (name in obj) {
3      if ( typeof( obj[name] ) != "function") {
4          document.writeln(name + " : " + obj[name]);
5      }
6  }
```

Removing an Object's Property

- To remove a property from an object if it has one (not removed from its prototype), use:

```
1  delete object.property-name
```

- Properties inherited from the prototype cannot be deleted unless the object had overriden them.

```
1  var e = new Employee( /* ... */ );
2  delete e.Title;     // Title is removed from e
```

Object Property Types

- Properties of an object can be configured to have the following attributes (or not):
  - Enumerable: Show up during enumeration(for.. in)
  - Configurable: Can be removed using delete, and the attributes can be changed after creation
  - Writeable: Can be modified after creation
- By default, all properties of an object are enumerable, configurable and writeable

Specifying Object Property types

- Can be done during Object creation with Object.create

```
1  var e = Object.create( Person,
2     { Title: {value: "Manager",
3        enumerable: true,
4        configurable: true,
5        writeable: false
6     } );
```

- Can be done after creation using Object.defineProperty

```
1  Object.defineProperty( Employee, "Title",
2     {value: "Manager",
3     enumerable: true,
4     configurable: true,
5     writable:false} );
```

Design Guidelines

- Use for...in loops to iterate over object's properties to make the code extensible
  - Avoid hardcoding property names if possible
  - Use instanceof rather than getPrototypeOf
- Try to fix the attributes of a property at object creation time. With very few exceptions, there is no need to change a property's attribute.

Class Activity

- Write a function to iterate over the properties of a given object, and identify those properties that it inherited from its prototype AND overrode it with its own values
  - Do not consider functions

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