CSC 347 - Concepts of Programming Languages

JavaScript OOP

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Learning Objectives

- Understand delegation-based object-oriented programming in JavaScript

JavaScript OOP

- Object literals `{}` are syntactic primities
- `class` declarations are not syntactic primitives, only syntactic sugar
- Delegation-based inheritance

Object Literals

- Objects have properties

```
var empty = {}; /* Object literal with no contents */
var person = {  /* Object literal with three properties */
  name: "Alice",
  age: 50,
  addr: "243 S Wabash Ave"
};
```

- Access properties

```
> [ person.name, person.name.length ]
[ 'Alice', 5 ]
```

- Update properties

```
> person.age = person.age + 1
51
```

- Access `undefined` property

```
> person.occupation
undefined                    /* huh???? */
```

- Access property of `undefined`

```
> person.occupation.length
Uncaught TypeError: Cannot read property 'length' of undefined
```

Object Properties

- Object is map from strings to values
- Dot notation when string has no spaces

```
var person = { name: "Alice", age: 50, addr: "243 S Wabash Ave" };
```

- Add a property `occupation`

```
person.occupation = "Developer";
```

- Add a property `happy place`

```
person["happy place"] = "Home";
```

- List all properties

```
> for (p in person) { console.log (p + ": " + person[p]); }
name: Alice
age: 50
addr: 243 S Wabash Ave
occupation: Developer
happy place: Home
```

- Turn object into a JSON string

```
> JSON.stringify(person)
'{"name":"Alice","age":50,"addr":"243 S Wabash Ave",
  "occupation":"Developer","happy place":"Home"}'
```

Function Properties

- Functions can be named or anonymous

```
// objects with number-property `n` and function-property `get`
var counter1 = { n: 0, get: function () { return this.n++; } };
var counter2 = { n: 0, get () { return this.n++; } };
```

- Invoke the functions

```
> [counter1.get(), counter2.get()]
[0, 0]
```

- Access the functions

```
> [counter1.get, counter2.get]
[ [Function: get],
  [Function: get] ]
```

- Serialize functions to string

```
> [counter1.get.toString(), counter2.get.toString()]
[ 'function () { return this.n++; }',
  'get () { return this.n++; }' ]
```

Access Properties from Functions

❗ `this` is mandatory

```
1 var counter1 = { n: 0, get: function () { return this.n++; } };
2 var counter3 = { n: 0, get: function () { return n++; } };
```

- Increment `counter1`

```
1 > counter1.get()
2 0
```

- Increment `counter3`

```
1 > counter3.get()
2 Uncaught ReferenceError: n is not defined
3     at Object.get (repl:1:43)
```

Encapsulation

- No private properties

```
1 var counter1 = { n: 0, get: function () { return this.n++; } };
```

- Increment `counter1`

```
1 > counter1.n = 30
2 > counter1.get()
3 30
```

Encapsulation

- Emulate encapsulation using closures

```
1 function createCounter () {
2   var n = 0;
3   return {
4     get: function () { return n++; }
5   };
6 };
7 var [c4a,c4b] = [createCounter(), createCounter()]
```

- `createCounter` returns an object literal with closure for function `get`
- `c4a` and `c4b` each have their own `n`

- Increment `c4a`

```
1 > c4a.get()
2 0
```

- Increment both `c4a` and `c4b`

```
1 > [c4a,c4b].map (x => x.get())
2 [ 1, 0 ]
```

Encapsulation

- Closure variables are not fields

```
1 function createCounter () {
2   var n = 0;
3   return {
4     get: function () {
5       console.log ("this.n=" + this.n);
6       return this.n++;
7     }
8   };
9 };
10 var c5 = createCounter ();
```

- Increment `c5`

```
1 > c5.get ();
2 this.n=undefined
3 NaN
```

Binding `this`

- JS binds `this` based on calling context. See here
  - `o.m()` is method context, `this===o`
  - `f()` is function context, `this===global/window`
  - `new C()` is constructor context, `this` is new object

- Access `this` from method context

```
1 var o = { getThis () { return this; } };
2 o.getThis() === o;     // true
```

- Access `this` from function context

```
1 var fThis = o.getThis; // save method as function
2 fThis() === o          // false --- this=o not closed above
3 fThis() === global     // true (in Node.js)
4 fThis() === window     // true (in Browser)
```

Binding `this`

JavaScript

```
1 var oJS = { n: -1, next () { this.n += 1; return this.n; }};
2 var fNext = oJS.next
3 fNext() // NaN --- closure does not bind this=oJS
```

- JS methods are just properties that hold functions
- `this` is not bound in the closure

Scala

```
1 object oScala { var n = -1; def next() = { this.n += 1; this.n } }
2 var fNext = oScala.next _
3 fNext() // 0 --- closure binds this=oScala
```

- Scala Methods are not Functions
- `this` is closed when converting method to function

Binding `this`

- What is wrong in the code below?

```
1 var o = {
2   v : 5,
3   add : function (xs) {
4     return xs.map(function(x){ return this.v + x; });
5   }
6 }
7 o.add([10,20,30]) // [ NaN, NaN, NaN ]
```

- Before EcmaScript5 fix: alias `this`

```
1 var o = {
2   v : 5,
3   add : function (xs) {
4     var me = this;
5     return xs.map(function(x){ return me.v + x; });
6   }
7 }
8 o.add([10,20,30]) // [ 15, 25, 35 ]
```

Binding `this`

- EcmaScript5 fix: manual binding

```
var o = {
  v : 5,
  add : function (xs) {
    return xs.map(function(x){ return this.v + x; }.bind(this));
  }
}
o.add([10,20,30]) // [ 15, 25, 35 ]
```

- EcmaScript6 fix: lambda notation

```
var o = {
  v : 5,
  add : function (xs) {
    return xs.map(x => this.v + x);
  }
}
o.add([10,20,30]) // [ 15, 25, 35 ]
```

Lambda Notation

- Lambda notation (fat arrow) uses the current value of `this`

```
1 var y = {getThese: function(xs){ return xs.map(x => this)}};
2 var z = {getThese: function(xs){ return xs.map(function(x){ return this; })}};
```

```
1 y.getThese([10,20,30])[0] === y      // true
2 z.getThese([10,20,30])[0] === global // true (in Node.js)
3 z.getThese([10,20,30])[0] === window // true (in Browswer)
```

Creating Objects

- Create an object with a function
- Call with *function context*
- Function builds and returns object literal

```
1 function createCounter () {
2   return {
3     n: -1,
4     next:  function () { return ++this.n; },
5     reset: function () { this.n = -1;      }
6   };
7 }
8 var c1 = createCounter (); // Function context
9 var c2 = createCounter ();
```

```
1 > [c1.next(), c1.next(), c1.next(), c1.reset(), c1.next(), c1.next()]
2 [ 0, 1, 2, undefined, 0, 1 ]
3 > [c2.next(), c2.next(), c2.next(), c2.reset(), c2.next(), c2.next()]
4 [ 0, 1, 2, undefined, 0, 1 ]
```

Creating Objects

- Call with *constructor context*
- Object created with `new` : implicitly passed to function as `this`

```
1 function Counter () {
2   this.n = -1;
3   this.next = function () { return ++this.n; },
4   this.reset = function () { this.n = -1; }
5 }
```

```
1 var c1 = new Counter (); // Constructor context
2 var c2 = new Counter ();
```

```
1 var cx = Counter (); // Function context! `this` points to global/window
2 // cx is undefined (no return statement in Counter)
```

```
1 > [c1.next(), c1.next(), c1.next(), c1.reset(), c1.next(), c1.next()]
2 [ 0, 1, 2, undefined, 0, 1 ]
3 > [c2.next(), c2.next(), c2.next(), c2.reset(), c2.next(), c2.next()]
4 [ 0, 1, 2, undefined, 0, 1 ]
```

❗ Every object has own set of methods `> c1.next === c2.next // false?!?`

Sharing Properties

- JS functions are objects, so can have properties
- Define properties on `prototype` object of function

```
1 function Counter () { this.n = -1; }
2 Counter.prototype.next  = function () { return ++this.n; }
3 Counter.prototype.reset = function () { this.n = -1;     }
4
5 var c1 = new Counter ();
6 var c2 = new Counter ();
```

```
1 > [c1.next(), c1.next(), c1.reset()]
2 [ 0, 1, 2, undefined]
3 > [c2.next(), c2.next(), c2.reset(), c2.next(), c2.next()]
4 [ 0, 1, undefined, 0, 1 ]
```

❗ `c1` and `c2` share `Counter.prototype`: `c1.next === c2.next // true`

Dynamically Update Methods at Runtime

```
1 function Counter () { this.n = -1; }
2 Counter.prototype.next  = function () { return this.n += 1; }
3 Counter.prototype.reset = function () { this.n = -1;     }
4
5 var c1 = new Counter ();
```

- Output

```
1 > [c1.next(), c1.next(), c1.next(), c1.reset(), c1.next(), c1.next()]
2 [ 0, 1, 2, undefined, 0, 1 ]
```

- Change the behavior of `next` and `reset`

```
1 > Counter.prototype.next  = function () { return this.n += 2; }
2 > Counter.prototype.reset = function () { this.n = -2;     }
```

- Output

```
1 > [c1.next(), c1.next(), c1.next(), c1.reset(), c1.next(), c1.next()]
2 [ 3, 5, 7, undefined, 0, 2 ]
```

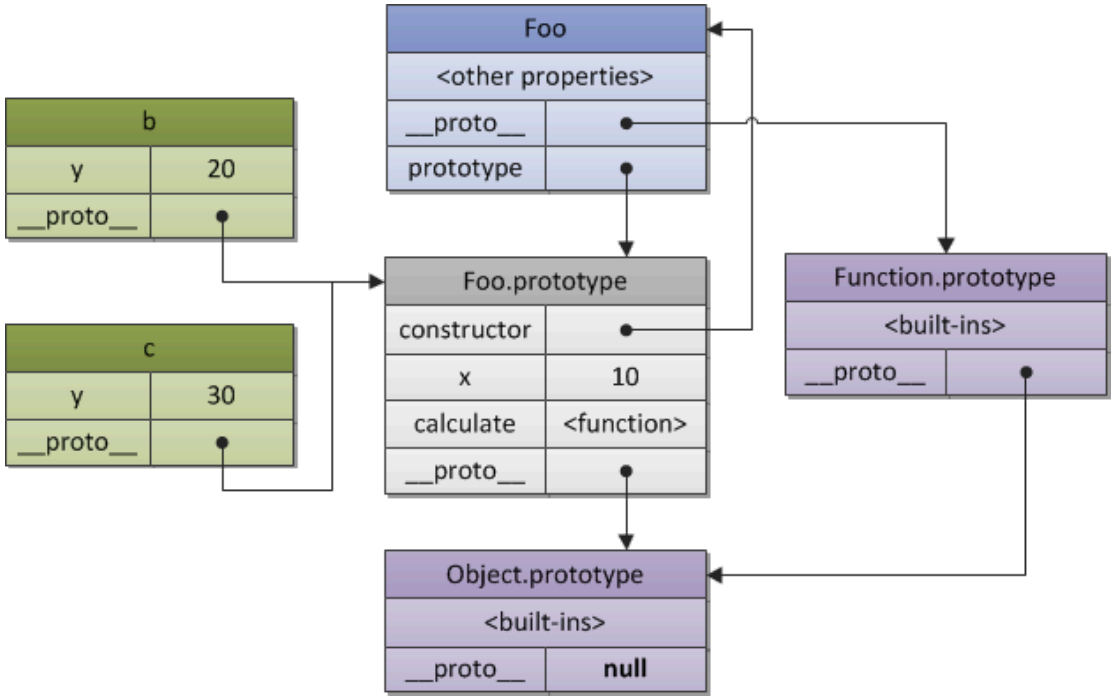
Delegation-based OOP

- `__proto__` *internal* property of object: points to another object
- If property does not exist, search `__proto__` *recursively* until found
  - Mozilla,
  - JavaScript Core,
  - JavaScript Prototype
- Terminology
  - Textbook: *delegation-based* inheritance
  - ECMAScript: *prototype-based* inheritance

Prototype vs. `__proto__`

- All objects have `__proto__`
- Functions have `prototype`
- In constructor context, new object's `__proto__` is set to the function's `prototype`

Prototype Implementation




```
1 function Foo(y) { this.y = y; }
2 Foo.prototype.x = 10;
3 Foo.prototype.calculate = function (z) {
4   return this.x + this.y + z;
5 };
6 var b = new Foo(20);
7 var c = new Foo(30);
```

Dynamically Change `__proto__` at Runtime

```
 1 function UpCounter () { this.n = -1; }
 2 UpCounter.prototype.next  = function () { return ++this.n; }
 3
 4 function DownCounter () { this.n = 1; }
 5 DownCounter.prototype.next  = function () { return --this.n; }
 6
 7 var c = new UpCounter ();
 8 c.next ();   // Returns 0
 9 c.next ();   // Returns 1
10
11 c.__proto__ = DownCounter.prototype
12 c.next ();   // Returns 0
13 c.next ();   // Returns -1
```

Delegation Chain

- The delegate object can also delegate

```
function ResetCounter () { this.reset(); }
ResetCounter.prototype.reset  = function () { this.n = -1; }
var c = new ResetCounter ();
c.next ();   // TypeError: c.next is not a function

function Counter () { this.n = -1; }
Counter.prototype.next  = function () { return ++this.n; }

ResetCounter.prototype.__proto__  = Counter.prototype
c.next ();   // Returns 0
c.next ();   // Returns 1
```

Classes

- JavaScript supports classes as syntactic sugar to create prototype chains

```
// implicit __proto__ = Object.prototype
class Counter {
  // constructor function
  constructor() { this.n = -1; }
  // method "next" created on Counter.prototype
  next() { return ++this.n; }
}
// extends sets __proto__
class ResetCounter extends Counter {
  // must call super constructor before doing other work
  constructor() { super(); this.reset(); }
  // method "reset" created on ResetCounter.prototype
  reset() { this.n = -1; }
}
class EvenCounter extends ResetCounter {
  next() { this.n += 2; return this.n; }
}
```

Summary

- Object literals are syntactic elements of JavaScript
- Delegation-based OOP: objects delegate responsibility to other objects (instead of inherit from other objects)
- Java-like `class` syntax is syntactic sugar for setting up delegation chains