CSC 447 - Concepts of Programming Languages

Delegation-based OOP in JavaScript

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Learning Objectives

❓ Does object-oriented programming require classes and inheritance?

- Describe delegation-based object-oriented programming in JavaScript
- Evaluate delegation chains

JavaScript OOP

- Object literals `{}` are syntactic primitives
- `class` declarations are not syntactic primitives, only syntactic sugar
- Delegation replaces class-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
'Alice'
> person.name.length
5
```

- Update properties

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

- Access `undefined` property

```
> person.occupation
undefined
```

- 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 counter2 = { n: 0, get: function () { return n++; } };
```

- Increment `counter1`

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

- Increment `counter2`

```
1 > counter2.get()
2 Uncaught ReferenceError: n is not defined at Object.get (repl:1:43)
```

Encapsulation

- All properties are public

```
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 // create array of counters, l-value uses again
8 // array notation to decompose into elements
9 var [c1,c2] = [createCounter(), createCounter()]
```

- `createCounter` returns an object literal with closure for function `get`
- `c1` and `c2` each have their own `n`

- Increment `c1`

```
1 > c1.get()
2 0
```

- Increment both `c1` and `c2`

```
1 > [c1,c2].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       console.log("n=" + n);
 7       return this.n++;
 8     }
 9   };
10 };
11 var c1 = createCounter ();
```

- Increment `c1`

```
1 > c1.get ();
2 this.n=undefined
3 n=0
4 NaN // from undefined++
```

Binding `this`

❓ What is `this` if there is no class?

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

Method context

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

Function context

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

Binding `this`

JavaScript

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

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

Scala

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

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

Binding `this`

🐞 What is wrong below?

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

- Inside `map` is function context, so `this` refers to `global/window`

- 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 ]
```

- Outside `map` but inside `add` is method context, so `this` refers to `o`
- Unlike `this`, ordinary variable `me` is closed

Binding `this`

- EcmaScript5 fix: manual binding

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

- Explicitly bind `this` in `map` (function context) to `this` in `add` (method context)

- EcmaScript6 fix: lambda notation

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

- In JS, lambda expressions are not ordinary functions
- Unlike in functions, `this` is closed in lambda expressions

Creating Objects

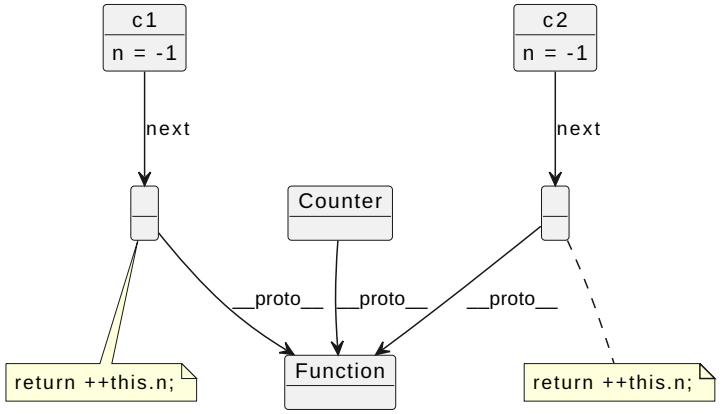
- Create an object with a function
- Function builds and returns object literal

```
1 function createCounter () {
2   return {
3     n: -1,
4     next:  function () { return ++this.n; }
5   };
6 }
7 var c1 = createCounter (); // Function context
8 var c2 = createCounter ();
9 [c1.next(), c1.next(), c2.next(), c1.next()] // [ 0, 1, 0, 2 ]
```

Creating Objects

- Call function using `new` : constructor context
- Binds `this` to newly created object inside function

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




```
1 var c1 = new Counter (); // Constructor context
2 var c2 = new Counter ();
3 [c1.next(), c1.next(), c2.next(), c1.next()] // [ 0, 1, 0, 2 ]
```

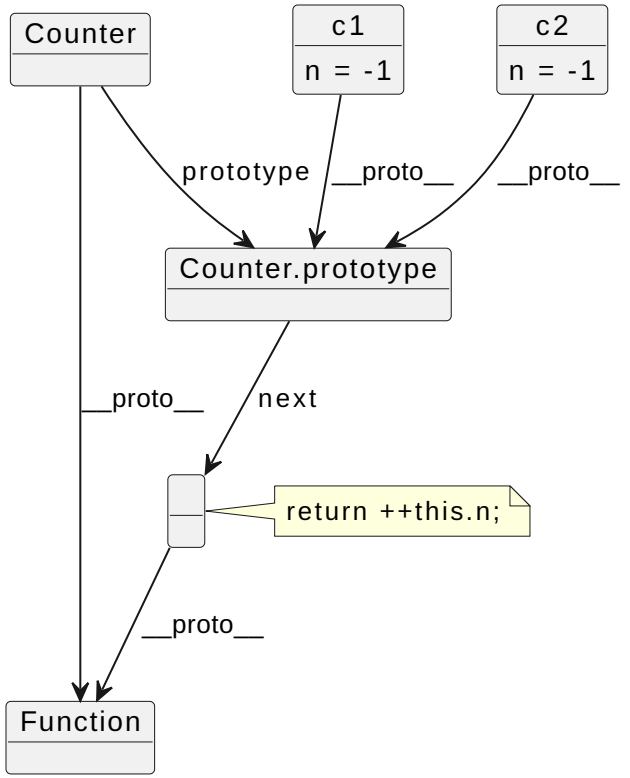
```
1 var cx = Counter (); // Function context!
2 cx.next() // Uncaught TypeError:
3           // cx is undefined (no return in Counter)
4 // instead, window now has properties n and next
5 [window.next(), window.next()] // [ 0, 1 ]
```

❗ Every object has own set of methods `c1.next != c2.next`

Sharing Properties

- JS functions are objects, so can have properties
- Define properties on `prototype` object of function
- Names looked up along delegation chain `__proto__`

```
1 function Counter () { this.n = -1; }
2 Counter.prototype.next  = function () {
3   return ++this.n;
4 }
5 var c1 = new Counter ();
6 var c2 = new Counter ();
7 [c1.next(), c1.next(),
8  c2.next(), c1.next()] // [0, 1, 0, 2]
```



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

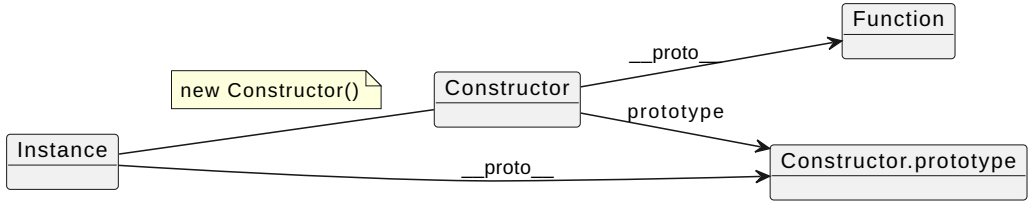
Delegation-based Inheritance

Delegation chain `__proto__`

- All objects have `__proto__`: points to another object
- Resolve names by searching `__proto__` recursively until found
  - Mozilla,
  - JavaScript Core,
  - JavaScript Prototype

Function companion `prototype`

- Only functions have `prototype`
- In constructor context, new object's `__proto__` is set to the function's `prototype`



Dynamically Update Methods at Runtime

```
function Counter () { this.n = -1; }
Counter.prototype.next  = function() {
  return this.n += 1;
}
var c1 = new Counter();
[c1.next(), c1.next(), c1.next()] // [0, 1, 2]
```

Change the behavior of `next`

```
Counter.prototype.next  = function () {
  return this.n += 2;
}
[c1.next(), c1.next(), c1.next()] // [4,6,8]
```

Dynamically Change `__proto__` at Runtime

```
1 function UpCounter () { this.n = -1; }
2 UpCounter.prototype.next  = function () { return ++this.n; }
3
4 var c = new UpCounter ();
5 c.next ();   // 0
6 c.next ();   // 1
```

Change delegation chain `__proto__`

```
1 function DownCounter () { this.n = 1; }
2 DownCounter.prototype.next  = function () { return --this.n; }
3
4 c.__proto__ = DownCounter.prototype
5 c.next ();   // 0
6 c.next ();   // -1
```

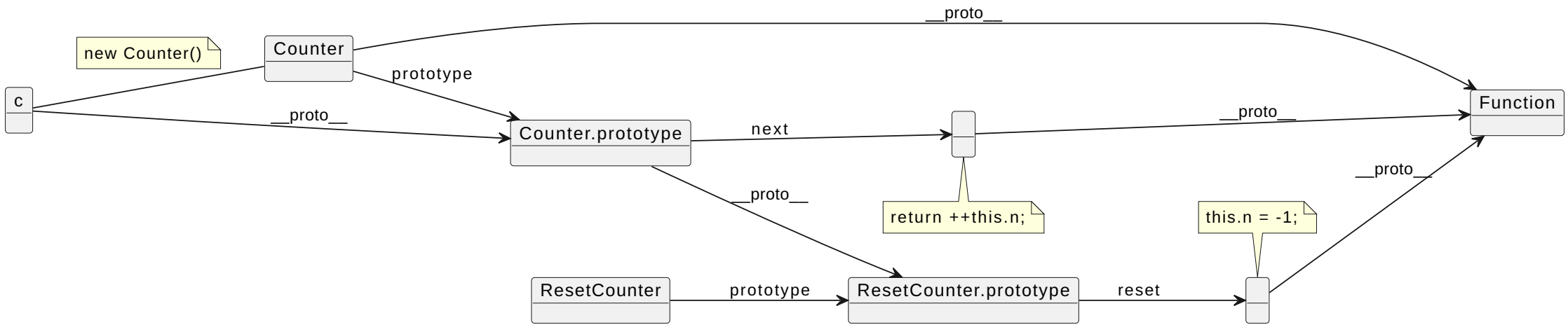
Delegation Chain

Create object

```
1 function Counter () { this.n = -1; }
2 Counter.prototype.next  = function () {
3   return ++this.n; }
4 var c = new Counter ();
5 c.next();  // 0
6 c.next();  // 1
7 c.reset(); // TypeError: c.reset is undefined
```

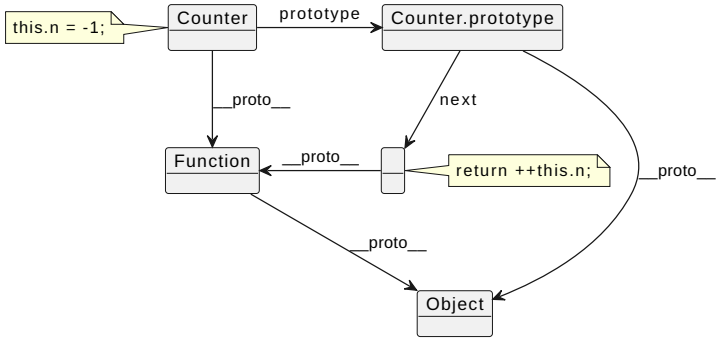
Extend delegation chain

```
1 function ResetCounter () { this.reset(); }
2 ResetCounter.prototype.reset  = function () {
3   this.n = -1; }
4 Counter.prototype.__proto__ = ResetCounter.prototype
5
6 c.reset(); // 0
7 c.next (); // 1
```

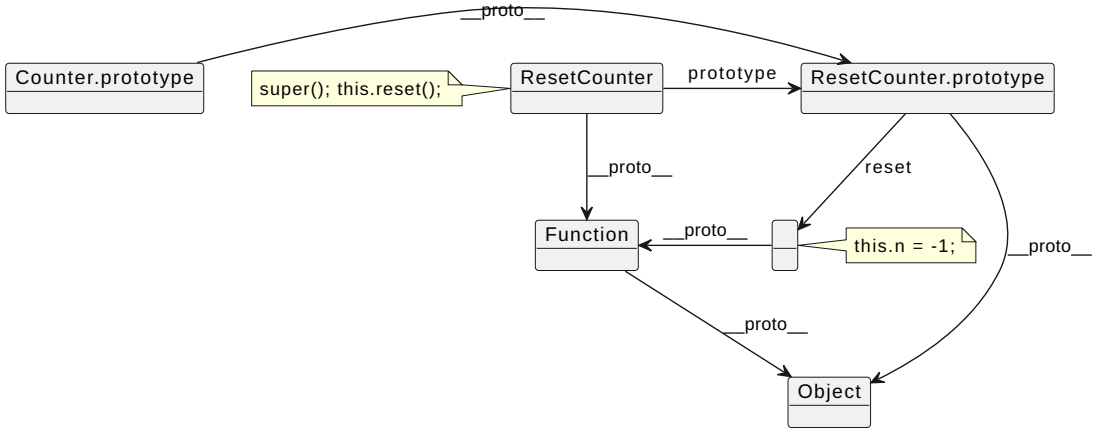


Classes: Create Delegation Chains

```
1 // sets Counter.prototype.__proto__ to Object.prototype
2 class Counter {
3   // function "Counter"
4   constructor() { this.n = -1; }
5   // method "next" created on Counter.prototype
6   next() { return ++this.n; }
7 }
```




```
1 // changes Counter.prototype.__proto__
2 // from Object.prototype
3 // to ResetCounter.prototype
4 class ResetCounter extends Counter {
5   // must call super constructor before doing other work
6   constructor() { super(); this.reset(); }
7   // method "reset" created on ResetCounter.prototype
8   reset() { this.n = -1; }
9 }
```



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