CSE 341
Lecture 26

OOP, prototypes, and inheritance

slides created by Marty Stepp
http://www.cs.washington.edu/341/

How to get a "class"?

- What if we want to create a class, not just one object?
  - JavaScript, unlike Java, does NOT have classes
  - we could emulate a constructor with a function:

```
// Creates and returns a new Point object.
function constructPoint(xValue, yValue) { // bad code
    return {
        x: xValue,  y: yValue,
        distanceFromOrigin: function() {
            return Math.sqrt(this.x * this.x +
                             this.y * this.y;
        }
    };
}
> var p = constructPoint(4, -3);
```

Problems with pseudo-constructor

```
function constructPoint(xValue, yValue) { // bad code
    return {
        x: xValue,  y: yValue,
        distanceFromOrigin: function() {
            return Math.sqrt(this.x * this.x +
                             this.y * this.y;
        }
    };
}
```

- ugly
- doesn't match the "new" syntax we're used to
- wasteful; stores a separate copy of the `distanceFromOrigin` method in each `Point` object

Functions as constructors

```
// Constructs and returns a new Point object.
function Point(xValue, yValue) {
    this.x = xValue;
    this.y = yValue;
    this.distanceFromOrigin = function() {
        return Math.sqrt(this.x * this.x + this.y * this.y);
    };
}
```

```
> var p = new Point(4, -3);
```

- a constructor is just a normal function!
- called with new like in Java

Functions as constructors

- in JavaScript, any function can be used as a constructor!
  - by convention, constructors' names begin in uppercase
  - when a function is called w/ `new`, it implicitly returns `this`

```
function Point(x, y) {
    this.x = x;
    this.y = y;
}
```

  - all global "classes" (`Number`, `String`, etc.) are functions acting as constructors, that contain useful properties

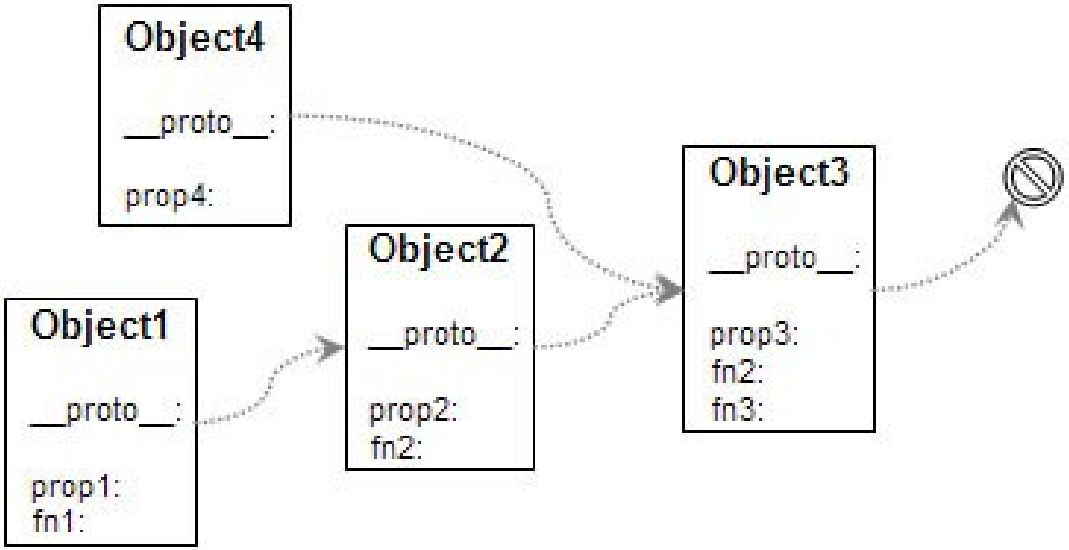
Functions as constructors

- any function can be called as a constructor or a function
- when any function called with `new`, JavaScript:
  - creates a new empty anonymous object
  - uses the new empty object as `this` within the call
  - implicitly returns the new object at the end of the call

- if you call a "constructor" without `new`, `this` refers to the global object instead
  - what happens if our "constructor" is called this way?

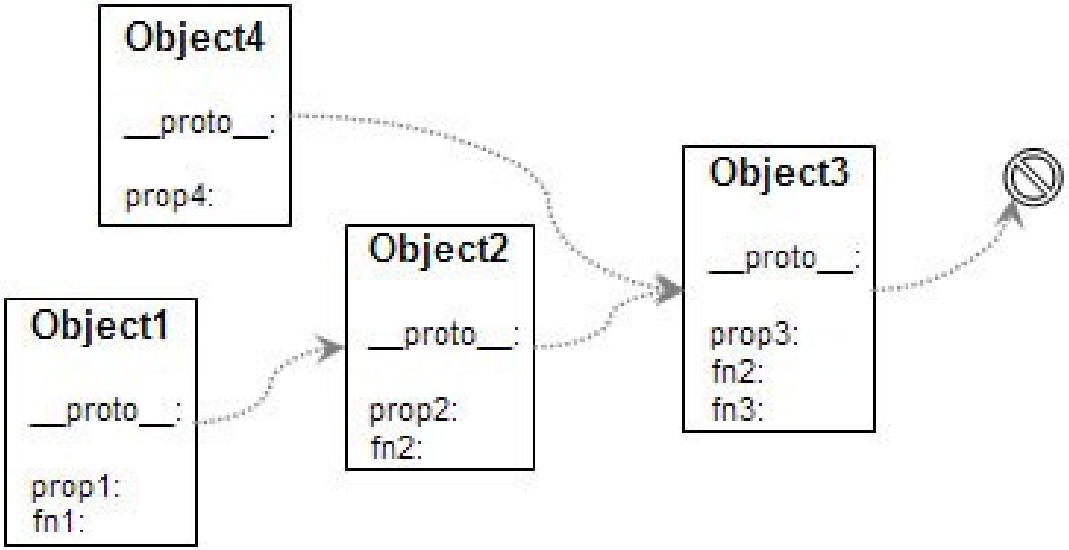
```
> var p = Point(4, -3);
```

Prototypes



- **prototype**: an ancestor of a JavaScript object
  - like a "super-object" instead of a superclass
  - a parent at the object level rather than at the class level

Prototypes



- every object contains a reference to its prototype
  - default: `Object.prototype`; strings → `String.prototype`; etc.
- a prototype can have a prototype, and so on
  - an object "inherits" all methods/data from its prototype(s)
  - doesn't have to make a copy of them; saves memory
  - prototypes allow JavaScript to mimic classes, inheritance

Functions and prototypes

```
// also causes Point.prototype to be defined
function Point(xValue, yValue) {
    ...
}
```

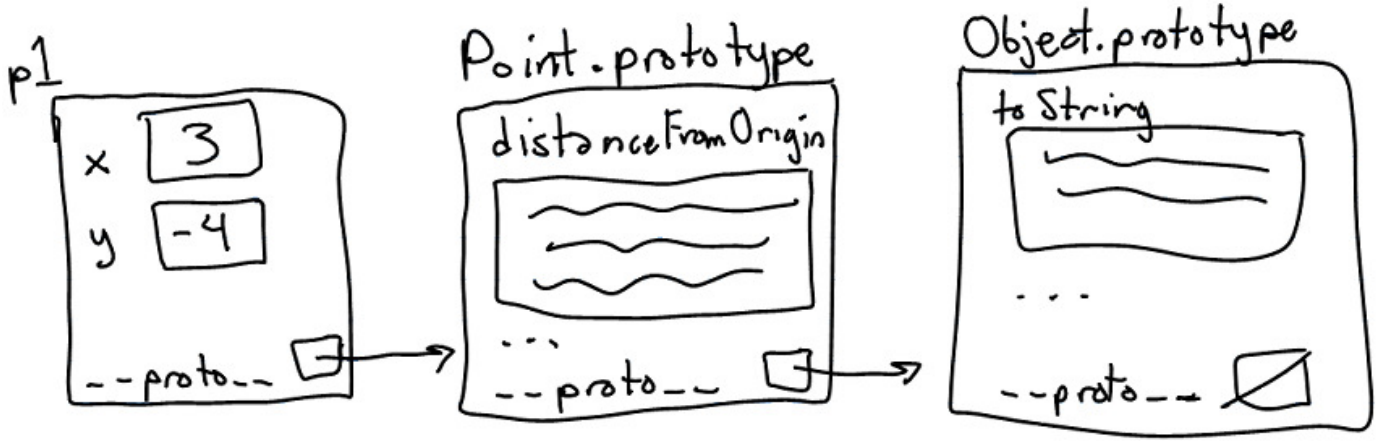
- every function stores a **`prototype`** object property in it
  - example: when we define our Point function (constructor), that creates a `Point.prototype`
  - initially this object has nothing in it (`{}`)
  - every object you construct will use the function's prototype object as its prototype
    - e.g. every new `Point` object uses `Point.prototype`

How constructors work

- when any function called with new, JavaScript:
  - creates a new empty anonymous object
  - uses the new empty object as `this` within the call
  - **attaches the function's `.prototype` property to the new object as its internal prototype**
  - implicitly returns the new object at the end of the call

The prototype chain

```
var p1 = new Point(4, -3);
```



- when you ask for a property (or method) in an object, JS:
  - sees if the **object itself** contains that property
  - if not, recursively checks the object's **prototype** for it
  - if not found, continues up the "prototype chain" until it finds the property or gives up with `undefined`

Augmenting a type via prototypes

```
// adding a method to the prototype
function.prototype.name = function(params) {
    statements;
};

Point.prototype.distanceFromOrigin = function() {
    return Math.sqrt(this.x * this.x +
                     this.y * this.y);
};
```

- adding a property to a prototype will give it to all objects that use that prototype
  - better than manually adding each method to each object

What goes in a prototype?

- generally only **methods** and **constants** (variables)
  - not objects' fields!
  - can also add "static" methods meant to be called on the prototype itself, e.g. `Math.abs`

- What would happen if we put the `x` and `y` fields in `Point.prototype`?

- *Exercise*: Add `distance` and `toString` methods.

Exercise solutions

```
// Distance between this point and the given point.
Point.prototype.distance = function(p) {
    var dx = this.x - p.x;
    var dy = this.y - p.y;
    return Math.sqrt(dx * dx + dy * dy);
};

// A string version of this object, e.g. "(3, -4)".
Point.prototype.toString = function() {
    return "(" + this.x + ", " + this.y + ")";
};
```

Modifying built-in prototypes

```
// add a 'contains' method to all String objects
String.prototype.contains = function(text) {
    return this.indexOf(text) >= 0;
};
```

- ANY prototype can be modified, including existing types
  - many JS add-on libraries do this to augment the language
  - not quite the same as adding something to a single object
- Exercise: Add a `reverse` method to all strings.
- Exercise: Add a `shuffle` method to all arrays.

Pseudo class-based-inheritance

```
function SuperClassName(parameters) { ... }
function SubClassName(parameters)   { ... }
SubClassName.prototype =                  // connect them
    new SuperClassName(parameters);
```

- to make a "subclass", tell its constructor to use an object of a "superclass" as its prototype
- why not just write it this way?

```
SubClassName.prototype = SuperClassName.prototype;
```

Pseudo-inheritance example

```
// Constructor for Point3D "subclass"
function Point3D(x, y, z) {
    this.x = x;
    this.y = y;
    this.z = z;
}

// set it to be a "subclass" of Point
Point3D.prototype = new Point(0, 0);

// override distanceFromOrigin method to be 3D
Point3D.prototype.distanceFromOrigin = function() {
    return Math.sqrt(this.x * this.x +
            this.y * this.y + this.z * this.z);
};
```

Problems with pseudo-inheritance

- there no equivalent of the `super` keyword
  - no easy way to call the superclass's constructor
- no built-in way to call an overridden superclass method
  - have to write it manually, e.g.

```
var d = Point.prototype.
                distanceFromOrigin.apply(this);
```

- solution: many JS libraries add class creation syntax, e.g.

```
Class.create(name, superclass, ...)
```

The instanceof keyword

expr instanceof ***ConstructorFunction***

- returns `true` if the given object was constructed by the given constructor, or is in the object's prototype chain

```
> var p = new Point(3, -4);
> var p3d = new Point3D(3, -4, 5);
> p instanceof Point
true
> p3d instanceof Point3D
true
> p3d instanceof Point
true
> "hello" instanceof Point || {} instanceof Point
false
```

Another type test: .constructor

```
> var p1 = new Point(3, -4);
> p1.constructor
function Point(xValue, yValue) { ... }
> var o = {};
> o.constructor
function Object() {[native code for Object.Object]}
```

- every object has a `constructor` property that refers to the function used to construct it (with `new`)
  - if the object was created without a constructor using `{}`, its .constructor property refers to the `Object()` function
  - `constructor` can be changed; `instanceof` will still work

The base2 library

```
load("base2.js");  // http://code.google.com/p/base2/
var Animal = Base.extend({
    constructor: function(name) {
        this.name = name;
    },
    name: "",
    eat: function() {
        this.say("Yum!");
    },
    say: function(message) {
        print(this.name + ": " + message);
    }
});
```

- intended to make inheritance/subtyping easier
- all classes extend a common constructor called Base

Java within JavaScript

- the Rhino VM is written in Java
  - it implements a layer of JavaScript on top of Java
- Rhino lets you *use Java classes* in JavaScript
  - combine Java's rich class library with JavaScript's dynamism and simpler syntax
- current trend: languages that on top of the JVM
  - **Clojure**: a Lisp dialect
  - **Scala**: an ML-like functional language
  - **Groovy**: a scripting language
  - JVM adaptations: JRuby, Jython, Erjang, JScheme, ...

Using Java classes in Rhino

```
importPackage(Packages.package);
importClass(Packages.package);
var name = new JavaClassName(params);
```

- Example:

```
> importPackage(Packages.java.util);
> var s = new TreeSet();
> s.addAll(Arrays.asList([2,7,1,2,4,1,2,4]));
> s
[1.0, 2.0, 4.0, 7.0]
```

Accessing class properties

JavaClassName.property
JavaClassName*["property***"]**

- Example:

```
> var console = new Scanner(System.in);
js: "<stdin>", line 44: missing name after . operator
js: var console = new Scanner(System.in);
js: ..................................^
> var console = new Scanner(System["in"]);
```

Some Java ↔ JS quirks

- JS Numbers are sometimes doubles when used in Java

```
> Arrays.asList([1, 2, 3])
[1.0, 2.0, 3.0]          <-- ArrayList<Double>
```

- to force usage of int, use Integer objects

```
> var list = new ArrayList();
> list.add(1);
> list.add(new Integer(2));
> list
[1.0, 2]
```

- char, long, short, byte are treated as Numbers in JS

```
> var s = new java.lang.String("hello");
> s.charAt(0)
104
```

More Java ↔ JS quirks

- sometimes JS → Java can't tell what type to use:

```
> var a = [4, 1, 7, 2];
> Arrays.sort(a);
The choice of Java constructor sort matching
  JavaScript argument types (object) is ambiguous;
  candidate constructors are:
    void sort(java.lang.Object[])
    void sort(long[])
    void sort(int[])
    ...
```

- Java collections/arrays DO have bounds checking

```
> var list = new ArrayList();
> list.get(7);
java.lang.IndexOutOfBoundsException: Index:7, Size:0
```

Implementing and extending

```
new InterfaceOrSubclass(object)   // or,
new JavaAdapter(Packages.superclass,
    interface1, ..., interfaceN, object)
```

- Example:

```
> var o = { compare: function(s1, s2) {
                return s1.length() - s2.length(); }};
> var comp = new Comparator(o);
> var set = new TreeSet(comp);
> set.add("goodbye");
> set.add("what");
> set.add("bye");
> set.add("hello");
> set
[bye, what, hello, goodbye]
```

Other direction: JS within Java

- Java 1.6 adds `javax.script` package to run JS code:

```
import java.io.*;
import javax.script.*;

public class RunJS {
  public static void main(String[] args) throws Throwable {
    ScriptEngine engine = new ScriptEngineManager().
                          getEngineByName("javascript");
    for (String arg : args) {
      engine.eval(new FileReader(arg));
    }
  }
}
```