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JavaScript

John Mitchell

Adapted by Mooly Sagiv

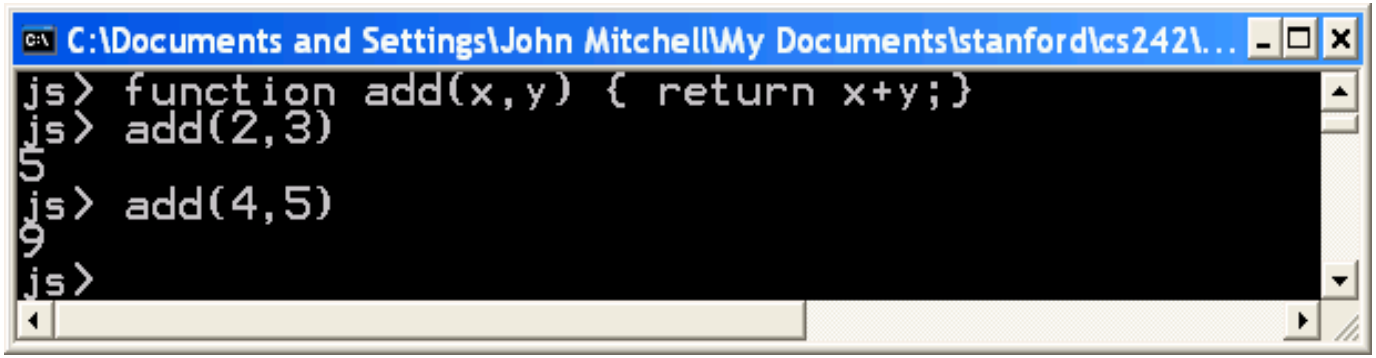
Simple Example

```
<!DOCTYPE html>
<html>
<body>

<h1>My First Web Page</h1>

<script>
document.write("<p>My First JavaScript</p>");
</script>

</body>
</html>
```

Another Example

```
<!DOCTYPE html>
<html>
<body>

<h1>My First Web Page</h1>

<p id="demo">My First Paragraph.</p>

<script>
document.getElementById("demo").innerHTML="My First JavaScript";
</script>

</body>
</html>
```

Stand-alone implementation

- Spidermonkey command-line interpreter
  - Read-eval-print loop
    - Enter declaration or statement
    - Interpreter executes
    - Displays value
    - Returns to input state
  - 

Why talk about JavaScript?

- Very widely used, and growing
  - Web pages, AJAX, Web 2.0
  - Increasing number of web-related applications
  - Adapted as a general purpose programming language
- Illustrates core PL concepts
  - First-class functions
  - Objects, in a pure form
- Some interesting trade-offs and consequences
  - Powerful modification capabilities
    - Add new method to object, redefine prototype, access caller …
  - Difficult to predict program properties in advance
    - Challenge for programmers, implementation, security, correctness

Keys to Good Language Design

- Motivating application
  - C: systems prog, Lisp: symbolic computation,
    Java: set-top box, JavaScript: web scripting
- Abstract machine
  - Underlying data structures that programs manipulate
  - JavaScript: web page -> document object model
- Theoretical considerations
  - ECMA Standard specifies semantics of JavaScript

What's a scripting language?

- One language embedded in another
  - A scripting language is used to write programs that produce inputs to another language processor
    - Embedded JavaScript computes HTML input to the browser
    - Shell scripts compute commands executed by the shell
- Common characteristics of scripting languages
  - String processing – since commands often strings
  - Simple program structure
    - Avoid complicated declarations, to make easy to use
    - Define things "on the fly" instead of elsewhere in program
  - Flexibility preferred over efficiency, safety
    - Is lack of safety a good thing? Maybe not for the Web!
  - Small programs

JavaScript History

- Developed by Brendan Eich at Netscape, 1995
  - Scripting language for Navigator 2
- Later standardized for browser compatibility
  - ECMAScript Edition 3 (aka JavaScript 1.5) -> ES5, …
- Related to Java in name only
  - Name was part of a marketing deal
- Various implementations available
  - Spidermonkey interactive shell interface
  - Rhino: http://www.mozilla.org/rhino/
  - Browser JavaScript consoles

Motivation for JavaScript

- Netscape, 1995
  - Netscape > 90% browser market share
  - Opportunity to do “HTML scripting language”
  - Brendan Eich

    “ I hacked the JS prototype in ~1 week in May
    And it showed! Mistakes were frozen early
    Rest of year spent embedding in browser” - ICFP talk, 2005
- Common uses of JavaScript have included:
  - Form validation
  - Page embellishments and special effects
  - Dynamic content manipulation
  - Web 2.0: functionality implemented on web client
    - Significant JavaScript applications: Gmail client, Google maps

Design goals

- Brendan Eich's 2005 ICFP talk
  - Make it easy to copy/paste snippets of code
  - Tolerate "minor" errors (missing semicolons)
  - Simplified onclick, onmousedown, etc., event handling, inspired by HyperCard
  - Pick a few hard-working, powerful primitives
    - First class functions for procedural abstraction
    - Objects everywhere, prototype-based
  - Leave all else out!

JavaScript design

- Functions based on Lisp/Scheme
  - first-class inline higher-order functions

    function (x) { return x+1; } ≡ λx. x+1
- Objects based on Smalltalk/Self
  - var pt = {x : 10, move : function(dx){this.x += dx}}
  - Functions are also objects
- Lots of secondary issues …
  - "In JavaScript, there is a beautiful, elegant, highly expressive language that is buried under a steaming pile of good intentions and blunders."

    Douglas Crockford

Sample “details”

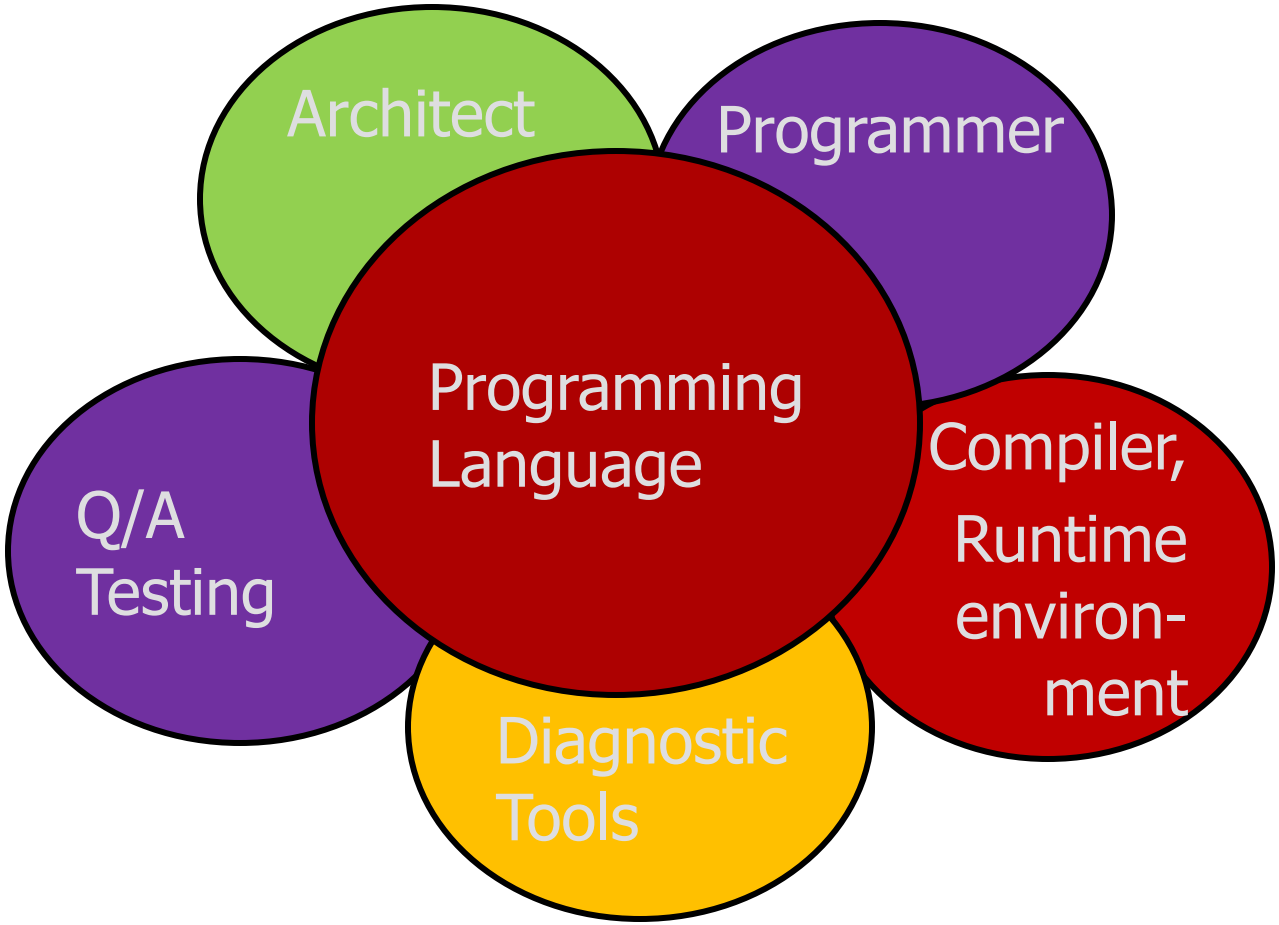
- Which declaration of g is used?

```
var f = function(){ var a = g();
                    function g() { return 1;};
                    function g() { return 2;};
                    var g = function() { return 3;}
                    return a;}
var result = f();       // what is result?
```

```
var scope = “global”;
function f() { print(scope);
               var scope = “local”;
               print(scope);
             }
```

// variable initialized here
//but defined throughout f

What makes a good programming language design?



Language syntax

- JavaScript is case sensitive
  - HTML is not case sensitive; onClick, ONCLICK, … are HTML
- Statements terminated by returns or semi-colons (;)
  - x = x+1; same as x = x+1
  - Semi-colons can be a good idea, to reduce errors
- "Blocks"
  - Group statements using { … }
  - Not a separate scope, unlike other languages (see later slide)
- Variables
  - Define a variable using the var statement
  - Define implicitly by its first use, which must be an assignment
    - Implicit definition has global scope, even if it occurs in nested scope

Web example: page manipulation

- Some possibilities
  - createElement(elementName)
  - createTextNode(text)
  - appendChild(newChild)
  - removeChild(node)

- Example: Add a new list item:

```
var list = document.getElementById(‘list1')
var newitem = document.createElement('li')
var newtext = document.createTextNode(text)
list.appendChild(newitem)
newitem.appendChild(newtext)
```

This example uses the browser Document Object Model (DOM)
We will focus on JavaScript as a language, not its use in the browser

Web example: browser events

```
<script type="text/JavaScript">
    function whichButton(event) {
      if (event.button==1) {
                alert("You clicked the left mouse button!") }
      else {
                alert("You clicked the right mouse button!")
      }}
</script>
…
<body onmousedown="whichButton(event)">
…
</body>
```

Mouse event causes page-defined function to be called

Other events: onLoad, onMouseMove, onKeyPress, onUnLoad

JavaScript primitive datatypes

- Boolean
  - Two values: *true* and *false*
- Number
  - 64-bit floating point, similar to Java double and Double
  - No integer type
  - Special values *NaN* (not a number) and *Infinity*
- String
  - Sequence of zero or more Unicode characters
  - No separate character type (just strings of length 1)
  - Literal strings using ' or " characters (must match)
- Special values
  - *null* and *undefined*
  - *typeof(null) = object; typeof(undefined)=undefined*

Type Checking

- Static types (Algol, C, Java, OCaml)
  - The type of expressions are checked at compile-time
- Dynamic types (lisp, scheme)
  - The type of expressions are checked at runtime
  - Soft typing can be used
- Duck-Typing (Python, Ruby, Javascript)
  - If an object can walk and swim like a duck, it is treated as a duck

JavaScript blocks

- Use { } for grouping; not a separate scope

```
var x = 3;
x;
{ var x = 4 ; x }
x;
```

- Not blocks in the sense of other languages
  - Only function calls and the *with* statement introduce a nested scope

JavaScript functions

- Declarations can appear in function body
  - Local variables, “inner” functions
- Parameter passing
  - Basic types passed by value, objects by reference
- Call can supply any number of arguments
  - functionname.length : # of arguments in definition
  - functionname.arguments.length : # args in call
- “Anonymous” functions (expressions for functions)
  - (function (x,y) {return x+y}) (2,3);
- Closures and Curried functions
  - function CurAdd(x){ return function(y){return x+y} };

More explanation on next slide

Function Examples

- Curried function

```
function CurriedAdd(x){ return function(y){ return x+y} };
g = CurriedAdd(2);
g(3)
```

- Variable number of arguments

```
function sumAll() {
  var total=0;
  for (var i=0; i< sumAll.arguments.length; i++)
        total+=sumAll.arguments[i];
  return(total);
}
sumAll(3,5,3,5,3,2,6)
```

Recursion

```
var hanoi = function hanoi(disc, src, aux, dst) {
   if (disc > 0) {
      hanoi(disc -1, src, dst, aux);
      document.writeln('Move disc' + disc +
        'from' + src +  ' dst ' + dst);
      hanoi(disc -1, aux, src, dst) ;
       }
}
```

```
var walk_the_DOM = function walk(node, func) {
    func(node);
    node = node.firstChild;
    while (node) {
        walk(node, func);
        node = node.nextSibling;
        }
}
```

Use of anonymous functions

- Simulate blocks by function definition and call

```
var u = { a:1, b:2 }
var v = { a:3, b:4 }
(function (x,y) {                          //  “begin local block”
    var tempA = x.a; var tempB =x.b;  //  local variables
    x.a=y.a; x.b=y.b;
    y.a=tempA; y.b=tempB
}) (u,v)                                          //   “end local block”
// Side effects on u,v  because objects are passed by reference
```

- Anonymous functions very useful for callbacks

```
setTimeout( function(){ alert("done"); }, 10000)
```

Objects

- Primitive types are immutable
- An object is a collection of named properties (mutable)
  - Simplistic view in some documentation: hash table or associative array
  - Can define by set of name:value pairs
    - objBob = {name: “Bob", grade: 'A', level: 3};
  - New properties can be added at any time
    - objBob.fullname = 'Robert';
  - A property of an object may be a function (=method)
- Functions are also objects
  - A function defines an object with method called “( )”

    function max(x,y) { if (x>y) return x; else return y;};

    max.description = “return the maximum of two arguments”;

Basic object features

- Creating and modifying objects

```
function Rectangle(w, h) ={this.width=w; this.height=h;}
var r = new Rectangle(8.5, 11);
r. area = function () { return this.width * this.height ;}
var a = r. area;
```

- Better to do it in the constructor

```
function Rectangle(w, h) {
   this.width = w; this.height = h ;
   this. area = function () { return this.width * this.height ;}
}
var r =  new Rectangle(8.5, 11);
var a = r.area() ;
```

Code and data can be shared via Prototypes

- Each object linked to prototype object
- Rectangle with shared area computation

```
function Rectangle(w, h) {
  this.width = w; this.height = h ;
  }
  Rectangle.prototype.area= function()  {
  return this.width * this.height ;}
  var r =  new Rectangle(8.5, 11);
var a = r.area() ;
```

Inheritance

- Javascript supports Prototype-based programming
  - As opposed to Java classes
- No need for casting
- Provides a reach set of code reuse patterns
- But syntax is ugly
  - See Javascript the good parts

Changing Prototypes

- Use a function to construct an object

```
function Car(make, model, year) {
    this.make = make;
    this.model = model;
    this.year = year;
}
```

- Objects have prototypes, can be changed

```
var c = new Car(“Tesla”,”S”,2014);
car.prototype.print = function () {
    return this.year + “ “ + this.make + “ “ + this.model;}
c.print();
```

Objects and *this*

- Property of the activation object for function call
  - In most cases, *this* points to the object which has the function as a property (or “method”)
  - Example :

```
var o  = {x : 10, f : function(){return this.x}}
o.f();
10
```

this is resolved dynamically when the method is executed

JavaScript functions and *this*

```
var x = 5; var y = 5;
function f() {return this.x + y;}
var o1 = {x : 10}
var o2 = {x : 20}
o1.g = f; o2.g = f;
```

o1.g() ➔ 15

o2.g() ➔ 25

var f1 = o1.g ; f1() ➔ 10

Both o1.g and o2.g refer to the same function.

Why are the results for o1.g() and o2.g() different ?

Local variables stored in “scope object”

Special treatment for nested functions

```
var x = 8
var o = { x: 10,
          f : function() {
                        function g(){ return this.x } ;
                        return g();
           }
};
o.f()
```

Function g gets the global object as its *this* property !

Language features

- Stack memory management
  - Parameters, local variables in activation records
- Garbage collection
  - Automatic reclamation of inaccessible memory
- Closures
  - Function together with environment (global variables)
- Exceptions
  - Jump to previously declared location, passing values
- Object features
  - Dynamic lookup, Encapsulation, Subtyping, Inheritance

Stack memory management

- Local variables in activation record of function

```
function f(x) {
    var y = 3;
    function g(z) { return y+z;};
    return g(x);
}
var x= 1; var y =2;
f(x) + y;
```

Closures

- Return a function from function call

```
function f(x) {
    var y = x;
    return function (z){y += z; return y;}
}
var h = f(5);
h(3);
```

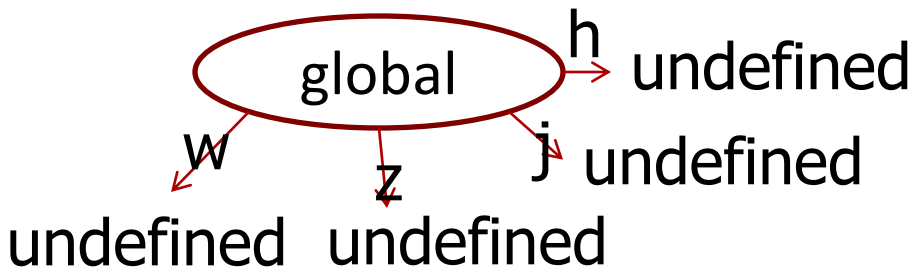
- Can use this idea to define objects with “private” fields

```
uniqueId function () {
  if (!arguments.callee.id) arguments.calee.id=0;
  return arguments.callee.id++;
};
```

– Can implement breakpoints

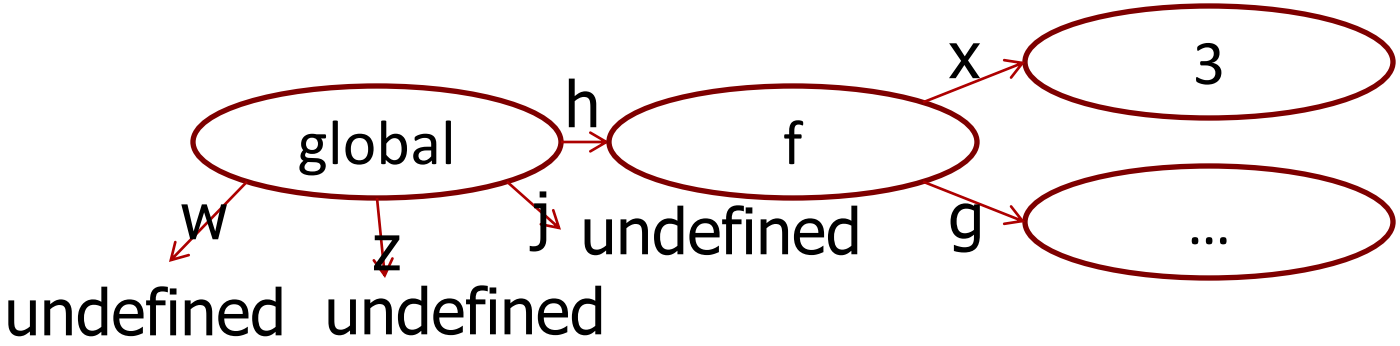
Implementing Closures

```
function f(x) {
   function g(y) { return x + y; };
   return g ;
 }
var h = f(3);
var j  = f(4);
var z = h(5);
var w = j(7);
```



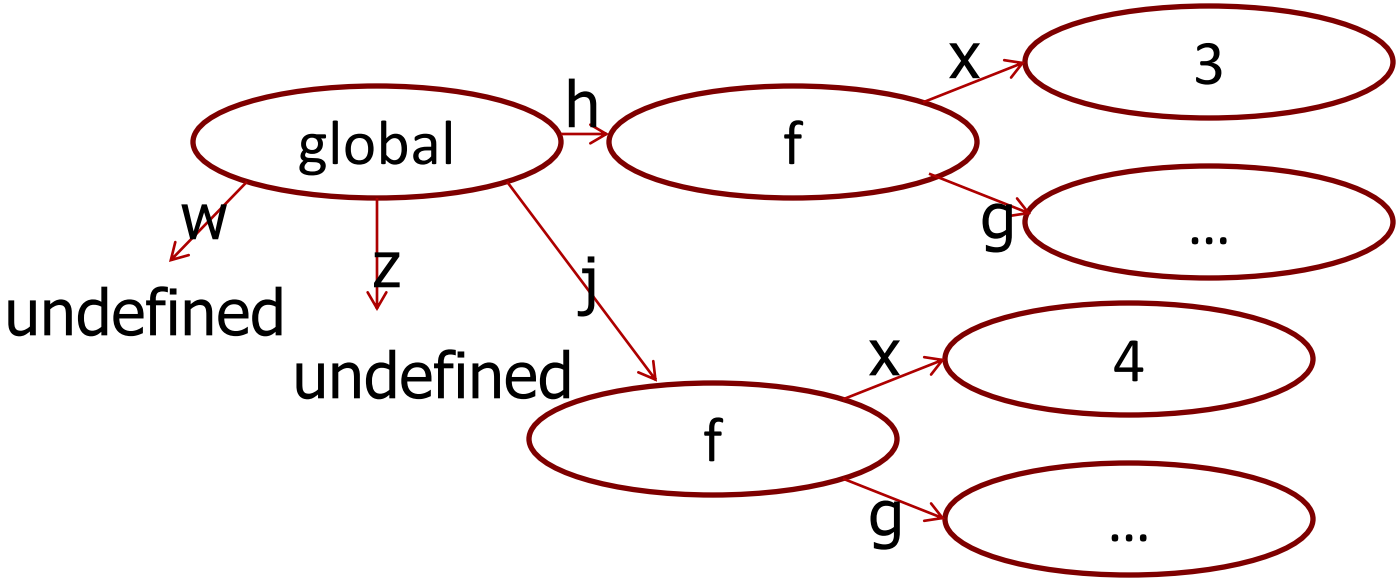
Implementing Closures(1)

```
function f(x) {
   function g(y) { return x + y; };
   return g ;
 }
var h = f(3);
var j  = f(4);
var z = h(5);
var w = j(7);
```



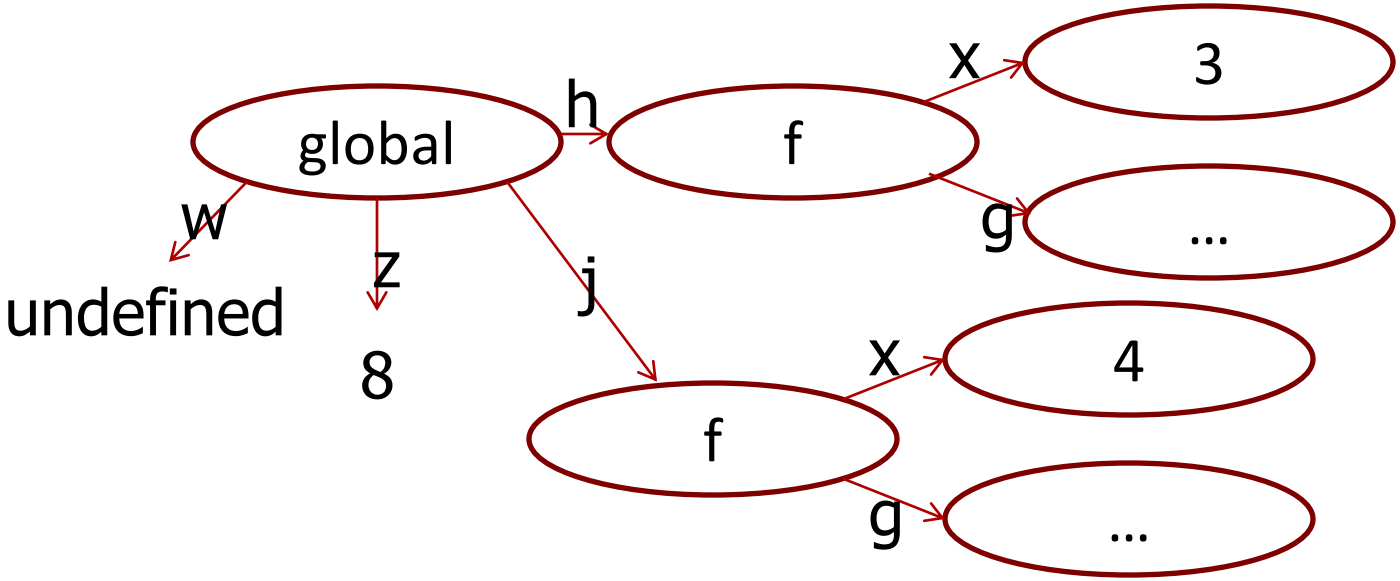
Implementing Closures(2)

```
function f(x) {
   function g(y) { return x + y; };
   return g ;
 }
var h = f(3);
var j  = f(4);
var z = h(5);
var w = j(7);
```



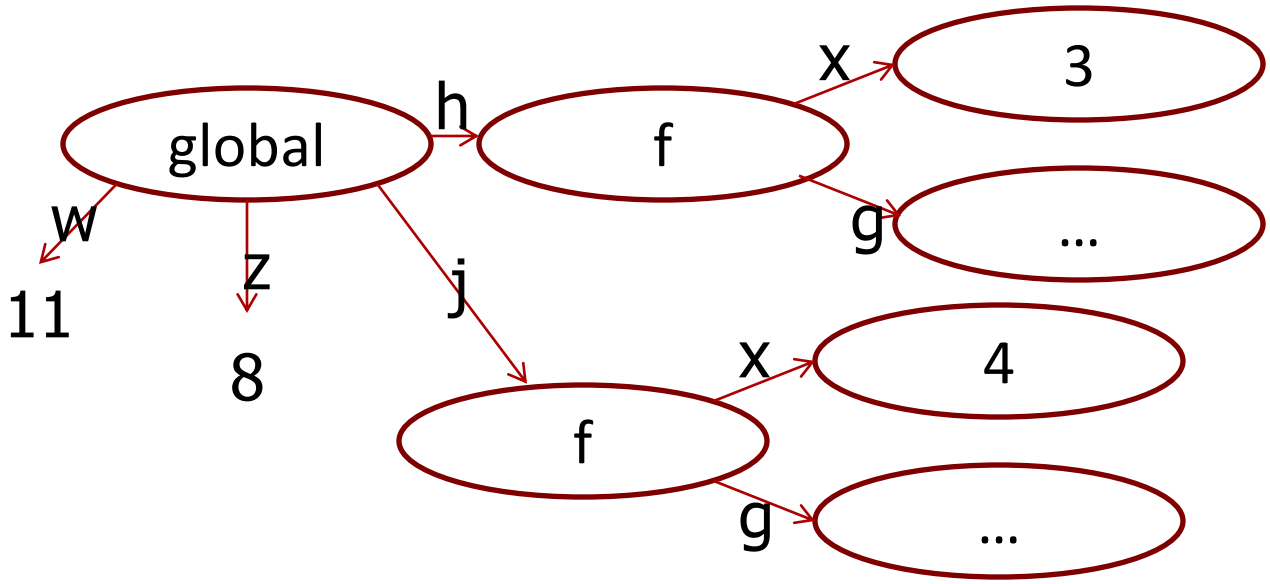
Implementing Closures(3)

```
function f(x) {
   function g(y) { return x + y; };
   return g ;
 }
var h = f(3);
var j  = f(4);
var z = h(5);
var w = j(7);
```



Implementing Closures(4)

```
function f(x) {
   function g(y) { return x + y; };
   return g ;
 }
var h = f(3);
var j  = f(4);
var z = h(5);
var w = j(7);
h= null;
```



Garbage collection

- Automatic reclamation of unused memory
  - Navigator 2: per page memory management
    - Reclaim memory when browser changes page
  - Navigator 3: reference counting
    - Each memory region has associated count
    - Count modified when pointers are changed
    - Reclaim memory when count reaches zero
  - Navigator 4: mark-and-sweep, or equivalent
    - Garbage collector marks reachable memory
    - Sweep and reclaim unreachable memory

Reference http://www.unix.org.ua/orelly/web/jscript/ch11_07.html

Discuss garbage collection in connection with memory management

Exceptions

- Throw an expression of any type

```
throw "Error2";
throw 42;
throw {toString: function() { return "I'm an object!"; } };
```

- Catch

```
try { …
} catch (e if e == “FirstException") {       // do something
} catch (e if e == “SecondException") {    // do something else
} catch (e){                                        // executed if no match above
}
```

Reference: http://developer.mozilla.org/en/docs/Core_JavaScript_1.5_Guide :Exception_Handling_Statements

Object features

- Dynamic lookup
  - Method depends on run-time value of object
- Encapsulation
  - Object contains private data, public operations
- Subtyping
  - Object of one type can be used in place of another
- Inheritance
  - Use implementation of one kind of object to implement another kind of object

Concurrency

- JavaScript itself is single-threaded
  - How can we tell if a language provides concurrency?
- AJAX provides a form of concurrency
  - Create XMLHttpRequest object, set callback function
  - Call request method, which continues asynchronously
  - Reply from remote site executes callback function
    - Event waits in event queue…
  - Closures important for proper execution of callbacks
- Another form of concurrency
  - use SetTimeout to do cooperative multi-tasking
    - Maybe we will explore this in homework …

Unusual features of JavaScript

- Some built-in functions
  - Eval (next slide), Run-time type checking functions, …
- Regular expressions
  - Useful support of pattern matching
- Add, delete methods of an object dynamically
  - Seen examples adding methods. Do you like this? Disadvantages?
  - myobj.a = 5; myobj.b = 12; delete myobj.a;
- Redefine native functions and objects (incl undefined)
- Iterate over methods of an object
  - for (variable in object) { statements }
- With statement (“considered harmful” – why??)
  - with (object) { statements }

JavaScript eval

- Evaluate string as code
  - The eval function evaluates a string of JavaScript code, in scope of the calling code
- Examples

```
var code = "var a = 1";
eval(code); // a is now '1‘
var obj = new Object();
obj.eval(code); // obj.a is now 1
```

- Most common use
  - Efficiently deserialize a large, complicated JavaScript data structures received over network via XMLHttpRequest
- What does it cost to have eval in the language?
  - Can you do this in C? What would it take to implement?

Other code/string conversions

- String computation of property names

```
var m = "toS"; var n = "tring";
Object.prototype[m + n] = function(){return undefined};
```

- In addition
  - for (p in o){....}
  - o[p]
  - eval(...)

    allow strings to be used as code and vice versa

Sample Javascript delights

- return
  {
   status: true
  };
- var length = 3;
  console.log(lenght);
- What does “a + b” mean
- False values: 0, Nan, ‘’, false, null, undefined

Lessons Learned

- Few constructs make a powerful language
- Simplifies the interpreter
- But the interaction can be hard to understand for programmers
  - JSLint
- Hard for compilation
  - JIT compilers
    - Spider Monkey, Mozilla, Safari, Chrome
- Some efforts to create safe Javasript sub-languages (Adsafe, Google Dart…)

References

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- Tutorial
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