Welcome

CS1101S Studio Session Week 9: *Environment Model, Array & Loop*

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Before We Start

Sumobot Contest

- Time: 6pm, 17 October 2018
- Venue: SR1, Level 2, COM1
- Free XP!
- Free food!

Overview

From Last Week

Immutable

- A constant holds a value inside it.
- `const x = 1;`
- Cannot hold another value.

Mutable

- A new value can be assigned to the same variable.
- `<variable_name> = <new_value>`
- `let y = 2;`
- To change the value inside `y = 3;`

From Last Week

Before Week 8

- Pure functional programming.
- Substitution model.
- Return value do not change if values of arguments are the same.

After Week 8

- Stateful programming.
- Environment model.
- Return value may vary even if values of arguments are the same.

Environment Model

Environment model

- Even though we supply the same values for all arguments, the return value of a function may still vary.
- Due to this, the substitution model breaks down.
- We have to introduce a new one and a better one:

  environment model
- It is an *upgrade* of substitution model + variable scoping.

Environment Model

Frame

- Each function call creates a new frame (similar to scope for variables).
- The initial frame is called global frame (global scope).
- Each frame contains a series of bindings of names and values.

Environment

- In order to find the variable, it is possible to search starting from the current local scope up to the global scope.
- Thus, all these corresponding frames are deterministic to the value of the variable. They are called the environment, a sequence of frames.

Environment Model

Frame & environment

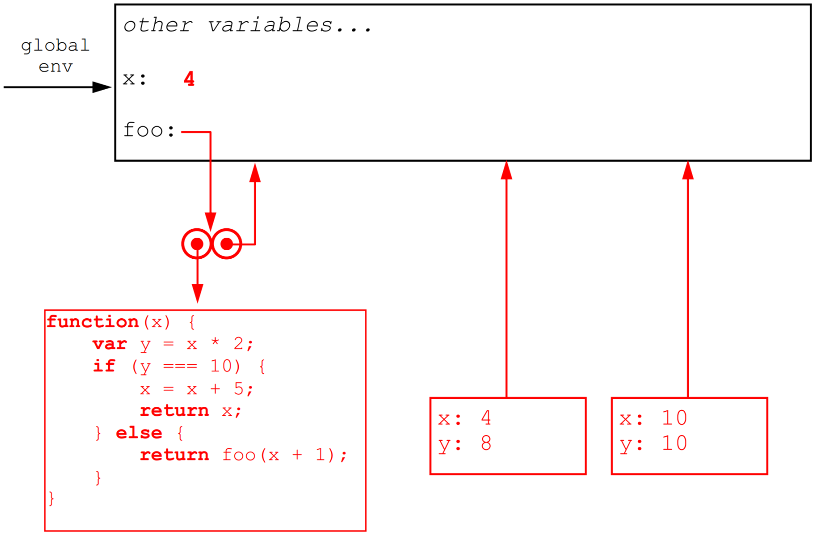
- Looks like a list.
- The head is the current frame, while the tail is pointing to the parent frames, called its **enclosing environment**.

Environment Model

What happens when we call a function?

- Create a new frame to extend the current environment.
- Evaluate actual arguments and bind their values to formal parameters.
- Local variables are bound to `undefined`.
- Evaluate the function body and send the return value to the enclosing environment.

Environment Model



```
function(x) {
    var y = x * 2;
    if (y === 10) {
        x = x + 5;
        return x;
    } else {
        return foo(x + 1);
    }
}
```

Environment Model

Exercise 1

- Assume the program stops at the comment.
- Draw the environment model diagram gradually.
- Also, identify the value of x at the point of that comment.

Environment Model

Exercise 1.1

```
let x = 0;

function environmentalist() {
    x = x + 1;

    function model(x) {
        x = x + 2;
        return x;
    }

    return model(x);
}
// Here
environmentalist();
x = environmentalist();
```

Environment Model

Exercise 1.2

```
let x = 0;

function environmentalist() {
    x = x + 1;

    function model(x) {
        x = x + 2;
        // Here
        return x;
    }

    return model(x);
}

environmentalist();
x = environmentalist();
```

Environment Model

Exercise 1.3

```
let x = 0;

function environmentalist() {
    x = x + 1;

    function model(x) {
        x = x + 2;
        return x;
    }

    return model(x);
}

environmentalist();
// Here
x = environmentalist();
```

Environment Model

Exercise 1.4

```
let x = 0;

function environmentalist() {
    x = x + 1;

    function model(x) {
        x = x + 2;
        return x;
    }

    return model(x);
}

environmentalist();
x = environmentalist();
// Here
```

Environment Model

Exercise 2

- The whole program has been evaluated.
- Draw the environment model diagram.

Environment Model

Exercise 2.1

```
let x = 4;

function foo(x) {
    let y = x * 2;

    if (y === 10) {
        x = x + 5;
        return x;
    } else {
        return foo(x + 1);
    }
}

foo(x);
```

Environment Model

Exercise 2.2

```
function alpha(x) {
    let y = 3;

    function beta(x) {
        y = y + x;
        return y;
    }

    return beta;
}

let haha = alpha(5);
haha(1);
```

Overview

Array

Array

- Array is effectively another linear data structure, similar as list.
- Empty array: `[]`
- Array with n element: `[1, 2, ..., n]`
- Access m^{th} element: `arr[m]`
- Array assignment: `arr[m] = "cs"`
- Array length: `array_length(arr)`

Array

Array and list

- List can be implemented using array.
- `pair(a, b)` is just `[a, b]`
- `list(a, b, c, d)` is just `[a, [b, [c, [d, []]]]]`

Array

Is array mutable? - using const

```
const arr = [1, 2, 3];
display(array_length(arr));

// Will this arise an error?
arr[1] = 3;

// Will this arise an error?
arr = [10, 20, 30];

// Will the length of the array change?
arr[4] = 5;
display(array_length(arr));
```

Array

Is array mutable? - using let

```
let arr = [1, 2, 3];

// Will this arise an error?
arr[1] = 3;

// Will this arise an error?
arr = [10, 20, 30];
```

Array

Is array mutable? - conclusion

- What do we really mean by “mutable”?
    - Is the whole data structure mutable?
    - Are the elements of the data structure mutable?
- Array assignment can increase the length of an array.

Array

High-dimensional Array

```
let arr2d = [[1, 2, 3], [4, 5], [6]];

// What's the length of the overall array?
display(array_length(arr2d));

// Does each sub-array have the same length?
display(array_length(arr2d[0]));
display(array_length(arr2d[1]));
```

Array

When to use array

- Implement data structure
- Implement sorting algorithm
- Use together with loop

Your task today ...

- Write a library for array, similar to the one for list.

Loop

while and for loop

- There are two kinds of loops available in Source:

  while and **for**

- They can be converted to each other.

```
for (E1; E2; E3) {
    // ...
}

E1;
while (E2) {
    // ...
    E3;
}
```

Loop

Use loop to “replace” recursion

- With mutable data, we can make use of loop to achieve the same outcome as recursion.

Use while to compute fact(n)

```
let fact = 1;
let k = 1;

while(k < n) {
  fact = fact * k;
  k = k + 1;
}
```

Loop

`continue` and `break`

- `continue`: terminates the current round of the loop and continues the loop with the next round.
- `break`: terminates the current round of the loop and also terminates the entire loop.

Loop & Array

Can you use array and loop to solve these problems?

- Factorial
- Square root
- Power function
- Fibonacci
- Greatest common divisor (GCD)
- Least common multiple (LCM)
- Hanoi tower
- Coin change
- Permutation / combination
- ...

Studio Group Problems

Let's discuss them now.

End

The End

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