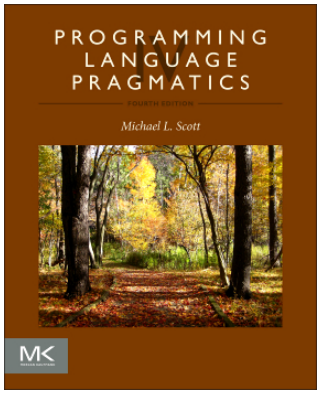
Semantics of Objects

17-363/17-663: Programming Language Pragmatics



Reading: PLP chapter 10

Ben Titzer Prof. Jonathan Aldrich

Object-Oriented Programming (OOP)

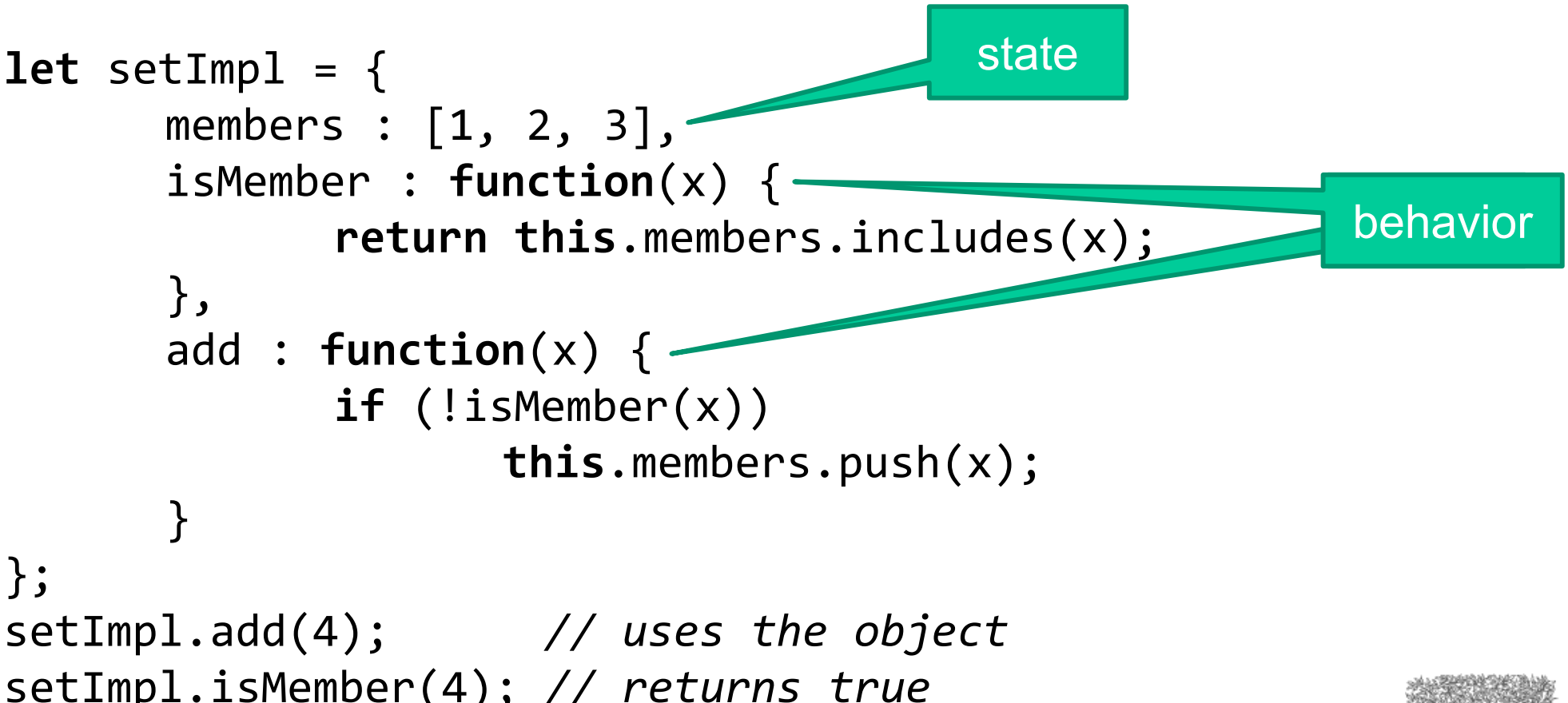
Three key aspects:

- Encapsulation
  - An object is a grouping of state and behavior, and hides its implementation choices from the outside world
- Inheritance
  - Objects are related, and we can capture shared behavior in a way that multiple kinds of objects can use it without defining it themselves
- Dynamic dispatch
  - The same operation can be implemented in different ways; each object knows what implementation to use for each of its operations

This aspect is special—it's the only one present in ALL object-oriented languages

Encapsulation

- An object is a grouping of state and behavior




```
let setImpl = {
        members : [1, 2, 3],
        isMember : function(x) {
                return this.members.includes(x);
        },
        add : function(x) {
                if (!isMember(x))
                        this.members.push(x);
        }
};
setImpl.add(4);       // uses the object
setImpl.isMember(4); // returns true
```

Encapsulation

- We can hide some of the object's state

```
interface IntSet {
        isMember : (x:number) => boolean
        add : (x:number) => void
}

let setImpl = { ... };
let set : IntSet = setImpl;

set.add(4);
set.isMember(4);
set.members
```

interface `IntSet` leaves out the `members` field. We can change that later without affecting clients.

Assigning to a variable of type `IntSet` hides everything that's not in the interface

It's a type error to access members that are not exposed in the interface

Classes

- A *class* is a template for objects. It defines structure & behavior used by all *instances* of the class

```
class IntSetClass {
        members : number[];
        constructor(m:number[]) {
                this.members = m;
        }
        isMember(x:number):boolean {
                return this.members.includes(x);
        }
        // add(x:number):void { ... }
}

let set2 : IntSetClass = new IntSetClass([1, 2]);
set2.add(5);
set2.isMember(5); // returns true
```

Dynamic Dispatch

- Every object knows its method implementations (whether defined in the object, or in that object's class)
- When we invoke a method, the code for that object is run

```
class Dog {
    talk() { console.log("woof!"); }
}
class Cat {
    talk() { console.log("meow!"); }
}
let animals = [new Dog(), new Cat() ];
for (let a of animals)
    a.talk(); // prints woof! meow!
```

Inheritance

- Inheritance lets us reuse code from one class in another
  - Prototype: a variant where you reuse code from another object (see JavaScript)

```
class Collection {
    constructor(ms) { this.members = ms; }
    isMember(x) { return this.members.includes(x); }
    add(x) { this.members.push(x); }
    addAll(a) { for (let x of a) this.add(x); }
}
class Set extends Collection {
    constructor(ms) { super(ms); }
    add(x) { if (!this.isMember(x)) { super.add(x); } }
}
let set = new Set([]);
set.add(3);
set.addAll([3, 4]);
set.isMember(4);
```

Exercise

- Draw the frames on the runtime stack when 4 is added to the set in the call set.addAll([3, 4]). Show all methods that are in from main() through push()

```
class Collection {
    constructor(ms) { this.members = ms; }
    isMember(x) { return this.members.includes(x); }
    add(x) { this.members.push(x); }
    addAll(a) { for (let x of a) this.add(x); }
}
class Set extends Collection {
    constructor(ms) { super(ms); }
    add(x) { if (!this.isMember(x)) { super.add(x); } }
}
let set = new Set([]);
set.add(3);
set.addAll([3, 4]);
```

Why Objects Matter

- Encapsulation (not specific to objects)
  - Separate reasoning about a single module enhances correctness & finding bugs
  - Ability to change the internals of a module without affecting others enhances software evolution
- Inheritance
  - Some code patterns are difficult to reuse in any other way
    - Typically when you have a reusable part and a customizable part, and they both call each other
  - That said, many uses of inheritance can (and should) be replaced with composition
    - Common guideline: prefer composition to inheritance
- Dynamic dispatch
  - Architecturally important – support multiple independent & interoperating implementations of a common interface
  - Examples all over the place: mobile phone apps, Linux device drivers, graphical user interfaces, MapReduce, web frameworks

Semantics

- We can use the static and dynamic semantics techniques we have learned to model objects

Source: Atshushi Igarashi, Benjamin Pierce, and Philip Wadler. Featherweight Java: a minimal core calculus for Java and GJ. OOPSLA 1999.