

Object Orientation

Definitions

- Give definitions for the following:
 - Object-oriented language
 - Object-oriented programming
- Then again, why bother?

Observations

- Object-oriented programming is not the same as programming in an object-oriented language
- Object-oriented languages are not all like Java

Outline

- 16.2 Object-oriented programming
 - OO in ML
 - Non-OO in Java
- 16.3 Object-oriented language features
 - Classes
 - Prototypes
 - Inheritance
 - Encapsulation
 - Polymorphism

```
public class Node {
    private String data;
    private Node link;
    public Node(String theData, Node theLink) {
        data = theData;
        link = theLink;
    }
    public String getData() {
        return data;
    }
    public Node getLink() {
        return link;
    }
}
```

A previous Java example: a node
used to build a stack of strings

Node Class

- Two fields, **data** and **link**
- One constructor that sets **data** and **link**
- Two methods: **getData** and **getLink**
- In the abstract, an object takes a message (“get data”, “get link”) and produces a response (a String or another object)
- An object is a bit like a function of type **message->response**

```
datatype message =  
  GetData  
  | GetLink;  
  
datatype response =  
  Data of string  
  | Object of message -> response;  
  
fun node data link GetData = Data data  
  | node data link GetLink = Object link;
```

Same OO idea in ML.

We have a type for messages and a type for responses.

To construct a node we call **node**, passing the first two parameters.

Result is a function of type **message -> response**.

Node Examples

```
- val n1 = node "Hello" null;
val n1 = fn : message -> response
- val n2 = node "world" n1;
val n2 = fn : message -> response
- n1 GetData;
val it = Data "Hello" : response
- n2 GetData;
val it = Data "world" : response
```

- Objects responding to messages
- `null` has to be something of the object type `(message->response)`; we could use

```
fun null _ = Data "null";
```

Stack Class

- One field, **top**
- Three methods: **hasMore, add, remove**
- Implemented using a linked list of **node** objects

```

datatype message =
  | IsNull
  | Add of string
  | HasMore
  | Remove
  | GetData
  | GetLink;

datatype response =
  | Pred of bool
  | Data of string
  | Removed of (message -> response) * string
  | Object of message -> response;

fun root _ = Pred false;

```

Expanded vocabulary of messages and responses, for both **node** and **stack**

Root class handles all messages by returning **Pred false**

```

fun null IsNull = Pred true
| null message = root message;

fun node data link GetData = Data data
| node data link GetLink = Object link
| node _ _ message = root message;

fun stack top HasMore =
  let val Pred(p) = top IsNull
  in Pred(not p) end
| stack top (Add data) =
  Object(stack (node data top))
| stack top Remove =
  let
    val Object(next) = top GetLink
    val Data(data) = top GetData
  in
    Removed(stack next, data)
  end
| stack _ message = root message;

```

```

- val a = stack null;
val a = fn : message -> response
- val Object(b) = a (Add "the plow.");
val b = fn : message -> response
- val Object(c) = b (Add "forgives ");
val c = fn : message -> response
- val Object(d) = c (Add "The cut worm ");
val d = fn : message -> response
- val Removed(e,s1) = d Remove;
val e = fn : message -> response
val s1 = "The cut worm " : string
- val Removed(f,s2) = e Remove;
val f = fn : message -> response
val s2 = "forgives " : string
- val Removed(_,s3) = f Remove;
val s3 = "the plow." : string
- s1^s2^s3;
val it = "The cut worm forgives the plow." : string

```

Inheritance, Sort Of

- Here is a `peekableStack` like the one in Java from Chapter Fifteen:

```
fun peekableStack top Peek = top GetData
| peekableStack top message = stack top message;
```

- This style is rather like a Smalltalk system
 - Message passing
 - Messages not statically typed
 - Unhandled messages passed back to superclass

Thoughts

- Obviously, not a good way to use ML
 - Messages and responses not properly typed
 - Skipped many “binding not exhaustive” messages from the previous example
- (Objective CAML is a dialect that integrates OO features into ML)
- The point is: it’s possible
- OO programming is not the same as programming in an OO language

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Java

- Java is better than ML at supporting an object-oriented style of programming
- But using Java is no guarantee of object-orientation
 - Can use static methods
 - Can put all code in one big class
 - Can use classes as records—public fields and no methods, like C structures

Classes Used As Records

```
public class Node {
    public String data; // Each node has a String...
    public Node link; // ...and a link to the next Node
}

public class Stack{
    public Node top; // The top node in the stack
}
```

A Non-OO Stack

```
public class Main {
    private static void add(Stack s, String data) {
        Node n = new Node();
        n.data = data;
        n.link = s.top;
        s.top = n;
    }
    private static boolean hasMore(Stack s) {
        return (s.top!=null);
    }
    private static String remove(Stack s) {
        Node n = s.top;
        s.top = n.link;
        return n.data;
    }
    ...
}
```

Note direct references to public fields—no methods required, data and code completely separate

Polymorphism

- In Chapter Fifteen: **WorkList** interface implemented by **Stack**, **Queue**, etc.
- There is a common trick to support this kind of thing in non-OO solutions
- Each record starts with an element of an enumeration, identifying what kind of **WorkList** it is...

A Non-OO Worklist

```
public class Worklist {
    public static final int STACK = 0;
    public static final int QUEUE = 1;
    public static final int PRIORITYQUEUE = 2;
    public int type; // one of the above Worklist types
    public Node front; // front Node in the list
    public Node rear; // unused when type==STACK
    public int length; // unused when type==STACK
}
```

The **type** field says what kind of **Worklist** it is.

Meanings of other fields depend on **type**.

Methods that manipulate **Worklist** records must branch on **type**...

Branch On Type

```
private static void add(Worklist w, String data) {
    if (w.type==Worklist.STACK) {
        Node n = new Node();
        n.data = data;
        n.link = w.front;
        w.front = n;
    }
    else if (w.type==Worklist.QUEUE) {
        the implementation of add for queues
    }
    else if (w.type==Worklist.PRIORITYQUEUE) {
        the implementation of add for priority queues
    }
}
```

Every method that operates on a **Worklist** will have to repeat this branching pattern

Drawbacks

- Repeating the branching code is tedious and error-prone
- Depending on the language, there may be no way to avoid wasting space if different kinds of records require different fields
- Some common maintenance tasks are hard—like adding a new kind of record

OO Advantages

- When you call an interface method, language system automatically dispatches to the right implementation for the object
- Different implementations of an interface do not have to share fields
- Adding a new class that implements an interface is easy—no need to modify existing code

Thoughts

- OO programming is not the same as programming in an OO language
 - Can be done in a non-OO language
 - Can be avoided in an OO language
- Usually, an OO language and an OO programming style do and should go together
 - You *usually* get a worse ML design by using an OO style (hint: avoid “binding not exhaustive”)
 - You *usually* get a better Java design by using an OO style (hint: avoid enumerations)

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Classes

- Most OO languages, including Java, have some kind of class construct
- Classes serve a variety of purposes, depending on the language:
 - Group fields and methods together
 - Are *instantiable*: the running program can create as many objects of a class as it needs
 - Serve as the unit of inheritance: derived class inherits from base class or classes

Classes

- More purposes:
 - Serve as a type: objects (or references to them) can have a class or superclass name as their static type
 - House *static* fields and methods: one per class, not one per instance
 - Serve as a labeled namespace; control the visibility of contents outside the class definition

Without Classes

- Imagine an OO language with no classes
- With classes, you create objects by instantiating a class
- Without classes, you could create an object from scratch by listing all its methods and fields on the spot
- Or, you could clone an existing *prototype* object and then modify parts of it

```
x = new Stack();
```

With classes:
instantiation

```
x = {  
    private Node top = null;  
    public boolean hasMore() {  
        return (top!=null);  
    }  
    public String remove() {  
        Node n = top;  
        top = n.getLink();  
        return n.getData();  
    }  
    ...  
}
```

Without classes:
raw object creation

```
x = y.clone();  
x.top = null;
```

Without classes:
prototype cloning

Prototypes

- A *prototype* is an object that is copied to make similar objects
- When making copies, a program can modify the values of fields, and can add or remove fields and methods
- Prototype-based languages (like Self) use this concept instead of classes

Without Classes

- Instantiation is only one use of classes
- Other things prototype-based languages must do without:
 - Classes as types: most prototype-based languages are dynamically typed
 - Inheritance: prototype-based languages use a related dynamic technique called *delegation*

Inheritance

- Simple enough in outline
 - Set up a relationship between two classes: a derived class and a base class
 - Derived class gets things from the base class
- But what a derived class gets from the base class (or classes) depends on the language...

Inheritance Questions

- More than one base class allowed?
 - Single inheritance: Smalltalk, Java
 - Multiple inheritance: C++, CLOS, Eiffel
- Forced to inherit everything?
 - Java: derived class inherits all methods, fields
 - Sather: derived class can rename inherited methods (useful for multiple inheritance), or just undefine them

Inheritance Questions

- Universal base class?
 - A class from which all inherit: Java's **Object**
 - No such class: C++
- Specification inherited?
 - Method obligations, as in Java
 - More specification: invariants, as in Eiffel
- Types inherited?
 - Java: all types of the base class

Inheritance Questions

- **Overriding, hiding, etc.?**
 - Java, roughly (skipping many details):
 - Constructors can access base-class constructors with **super**; implicit call of no-arg super constructor
 - New instance method of the same name and type overrides inherited one; overridden one can be called using **super**
 - New field or static method hides inherited ones; still accessible using **super** or base class static types
- **Languages differ considerably**

Encapsulation

- Found in virtually all modern programming languages, not just OO ones
- Encapsulated program parts:
 - Present a controlled interface
 - Hide everything else
- In OO languages, objects are encapsulated
- Different languages do it differently

Visibility Of Fields And Methods

- Java: four levels of visibility
 - **private**: only within class
 - Default access: throughout package
 - **protected**: package + derived classes
 - **public**: everywhere
- Some OO languages (Smalltalk, LOOPS, Self) have less control: everything public
- Others have more: in Eiffel, features can be exposed to a specific set of client classes

Polymorphism

- Found in many languages, not just OO ones
- Special variation in many OO languages:
 - When different classes have methods of the same name and type, like a stack class and a queue class that both have an **add** method
 - When language permits a call of that method in contexts where the class of the object is not known statically

Example: Java

```
public static void flashoff(Drawable d, int k) {  
    for (int i = 0; i < k; i++) {  
        d.show(0,0);  
        d.hide();  
    }  
}
```

- Here, **Drawable** is an interface
- Class of object referred to by **d** is not known at compile time

Dynamic Dispatch

- In Java, static type of the reference may be a superclass or interface of the actual class
- At runtime, the language system must find the right method for the actual class
- That's *dynamic dispatch*: the hidden, implicit branch-on-class to implement method calls
- Optional in C++; always used in Java and most other OO languages

Implementation And Type

- In Java, two mechanisms:
 - A class inherits both types and implementation from its base class
 - A class gets additional types (but no implementation) by implementing interfaces
- Partially separates inheritance of implementation and inheritance of type
- Other OO languages differ in how much they separate these two

Implementation And Type

- In C++, no separation:
 - One mechanism for general inheritance
 - For inheriting type only, you can use an abstract base class with no implementations
- In Sather, complete separation:
 - A class can declare that it *includes* another class, inheriting implementation but not type
 - A class can declare that it is a subclass of an abstract class, inheriting type but not implementation (like Java interfaces)

About Dynamic Typing

- Some OO languages use dynamic typing: Smalltalk, Self
- An object may or may not be able to respond to a particular message—no compile-time check (like our ML trick)
- Total freedom: program can try using any method for any object
- Polymorphism is not relevant here

Conclusion

- Today, a cosmopolitan perspective:
 - Object-oriented programming is not the same as programming in an object-oriented language
 - Object-oriented languages are not all like Java
- There is no single OO programming style or set of OO language features: they are often debated and they are evolving
- Be skeptical of definitions!