Programming Languages

OOP

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What is OOP? (part I)

The *object* idea:

- bundling of data (*data members*) and operations (*methods*) on that data
- restricting access to the data

An object contains:

- **data members** : arranged as a set of named fields
- **methods** : routines which take the object they are associated with as an argument
  (known as *member functions* in C++)
- **constructors** : routines which create a new object

A class is a construct which defines the data, methods and constructors associated with all of its instances (objects).

What is OOP? (part II)

The *inheritance* and *dynamic binding* ideas:

- classes can be extended (*inheritance*):
  - by adding new fields
  - by adding new methods
  - by *overriding* existing methods (changing behavior)

  If class B extends class A, we say that B is a *subclass* or *derived* class of A, and A is a *superclass* or *base* class of B.
- dynamic binding : wherever an instance of a class is required, we can also use an instance of any of its subclasses; when we call one of its methods, the overridden versions are used.
- There should be an *is-a* relationship between a derived class and its base class.

Styles of OOLs

- in class-based OOLs, each object is an instance of a class (Java, C++, C#, Ada95, Smalltalk, OCaml, etc.)
- in prototype-based OOLS, each object is a clone of another object, possibly with modifications and/or additions (Self, Javascript)

Other common OOP features

- multiple inheritance
  - C++
  - Java (of interfaces only)
  - problem: how to handle diamond shaped inheritance hierarchy
- classes often provide package-like capabilities:
  - visibility control
  - ability to define types and classes in addition to data fields and methods

Java Features

- an imperative language (like C++, Ada, C, Pascal)
- is interpreted (like Scheme, APL)
- is garbage-collected (like Scheme, ML, Smalltalk, Eiffel, Modula-3)
- can be compiled
- is object-oriented (like Eiffel, more so than C++, Ada)
- a successful hybrid for a specific-application domain
- a reasonable general-purpose language for non-real-time applications

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- Work in progress: language continues to evolve
- C# is latest, incompatible variant

Original design goals (white paper 1993)

- simple
- object-oriented (inheritance, polymorphism)
- distributed
- interpreted
- multi-threaded
- robust
- secure
- architecture-neutral

Obviously, “simple” was dropped.

Portability

Critical concern: write once – run everywhere

Consequences:

- portable interpreter
- definition through virtual machine: the JVM
- run-time representation has high-level semantics
- supports dynamic loading
- high-level representation can be queried at run-time to provide reflection
- dynamic features make it hard to fully compile, safety requires numerous run-time checks

Contrast with conventional systems languages

Conventional imperative languages are fully compiled:

- run-time structure is machine language
- minimal run-time type information
- language provides low-level tools for accessing storage
- safety requires fewer run-time checks because compiler (least for Ada and somewhat for C++) can verify correctness statically
- languages require static binding, run-time image cannot be easily modified
- different compilers may create portability problems

Notable omissions

- no operator overloading (syntactic annoyance)
- no separation of specification and body
- no enumerations until latest language release
- no generic facilities until latest language release

Statements

Most statements are like their C counterparts:

- `switch` (including C's falling through behavior)
- `for`
- `if`
- `while`
- `do ... while`
- `break` and `continue`
  - Java also has *labeled* versions of `break` and `continue`, like Ada.
- `return`

Java has no `goto`!

The simplest Java program

```
class HelloWorld {
  public static void main (String[] args) {
    System.out.println("Hello,␣world");
  }
}
```

Classes in Java

Encapsulation of type and related operations

```
class Point {
  private double x, y;  // private data members

  public Point (double x, double y) { // constructor
    this.x = x;   this.y = y;
  }

  public void move (double dx, double dy) {
    x += dx;  y += dy;
  }

  public double distance (Point p) {
    double xdist = x - p.x, ydist = y - p.y;
    return Math.sqrt(xdist * xdist + ydist * ydist);
  }

  public void display () { ... }
}
```

Extending a class

```
class ColoredPoint extends Point {
  private Color color;

  public ColoredPoint (double x, double y,
                       Color c) {
    super(x, y);
    color = c;
  }

  public ColoredPoint (Color c) {
    super(0.0, 0.0);
    color = c;
  }

  public Color getColor () { return color; }

  public void display () { ... }  // now in color!
}
```

Dynamic dispatching

```
Point p1 = new Point(2.0, 3.0);
ColoredPoint cp1 = new ColoredPoint(2.0, 3.0, Blue);

Point p2 = p1;                  // OK
Point p3 = cp1;                 // OK

ColoredPoint cp2 = cp1;  // OK
ColoredPoint cp3 = p1;   // Error

cp1.move(1.0, 1.0);  // cp1 and p3 affected

p1.display();    // Point's display
cp1.display();   // ColoredPoint's display
p3.display();    // ColoredPoint's display
```

Classes in C++

The same classes, translated into C++:

```
class Point {
  double m_x, m_y;  // private data members

public:

  Point (double x, double y)  // constructor
    : m_x(x), m_y(y) { }

  virtual ~Point () { }

  virtual void move (double dx, double dy) {
    m_x += dx;  m_y += dy;
  }

  virtual double distance (const Point& p) {
    double xdist = m_x - p.m_x, ydist = m_y - p.m_y;
    return sqrt(xdist * xdist + ydist * ydist);
  }

  virtual void display () { ... }
};
```

Extending a class

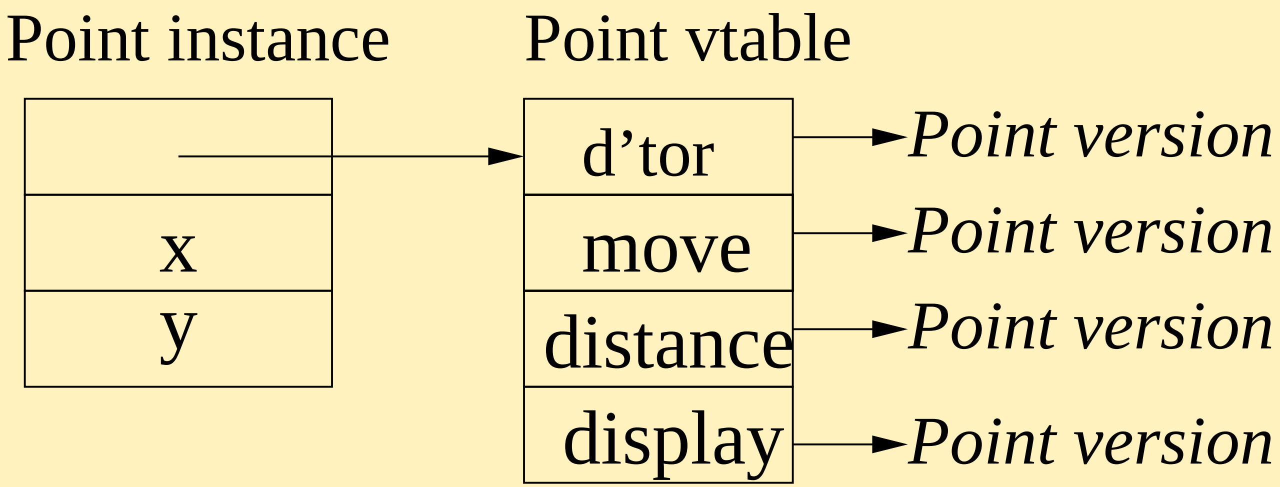
```
class ColoredPoint : public Point {
  Color color;

public:

  ColoredPoint (double x, double y,
                Color c) : Point(x, y), color(c) {
    color = c;
  }

  ColoredPoint (Color c) : Point(0.0, 0.0), color(c) { }

  virtual Color getColor () { return color; }

  virtual void display () { ... }  // now in color!
};
```

Dynamic dispatching

```
Point *p1 = new Point(2.0, 3.0);
ColoredPoint *cp1 = new ColoredPoint(2.0, 3.0, Blue);

Point *p2 = p1;                // OK
Point *p3 = cp1;               // OK

ColoredPoint *cp2 = cp1;   // OK
ColoredPoint *cp3 = p1;    // Error

cp1->move(1.0, 1.0);  // cp1 and p3 affected

p1->display();    // Point's display
cp1->display();   // ColoredPoint's display
p3->display();    // ColoredPoint's display
```

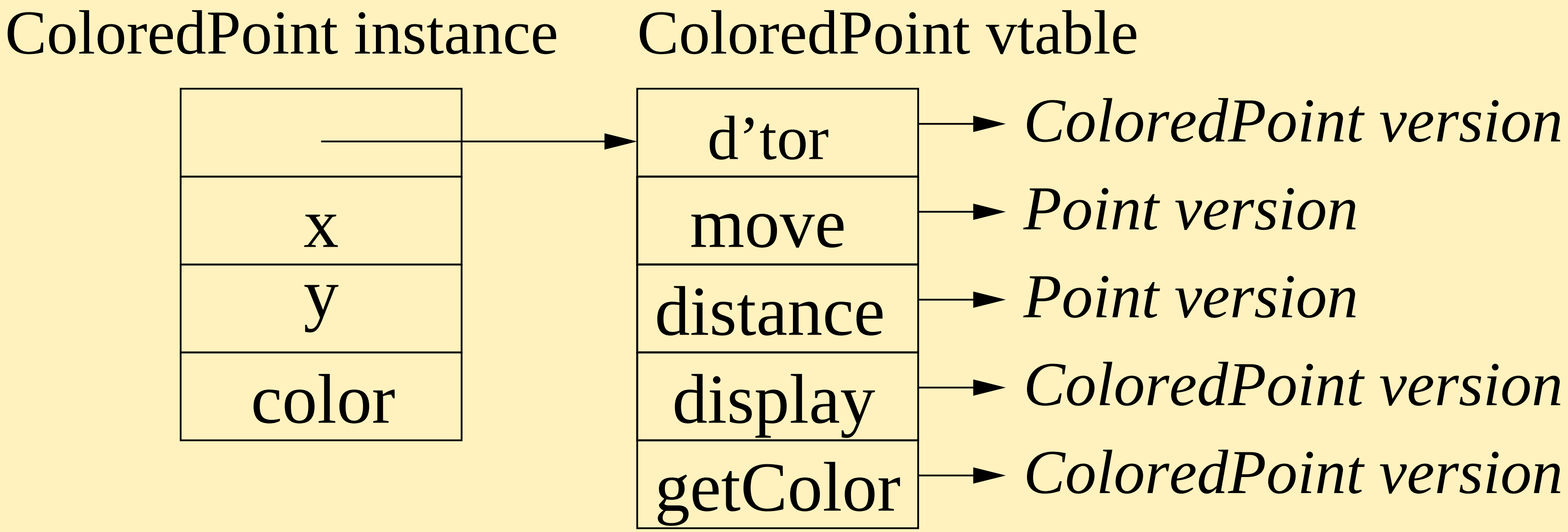
Implementation: the vtable

A typical implementation of a class in C++; using `Point` as an example:



An extended vtable

For `ColoredPoint`, we have:



Non-virtual member functions are never put in the vtable

Method modifiers

- access modifiers:
  - `public`
  - `protected`
  - `package`
  - `private`
- `abstract`
- `static`
- `final`
- `synchronized`
- `native`
- `strictfp` (strict floating point)

A new construct: interfaces

A Java `interface` allows otherwise unrelated classes to satisfy a given requirement.

This is orthogonal to inheritance.

- **inheritance**: an `A` *is-a* `B` (has the attributes of a `B`, and possibly others)
- **interface**: an `A` *can-do* `X` (and possibly other unrelated actions)
- interfaces are a better model for multiple inheritance

See blackboard for implementation details (also in Scott, section 9.4.3)

Interface Comparable

```
public interface Comparable {
  public int CompareTo (Object x) throws
    ClassCastException;
  // returns -1 if this < x,
  //          0 if this = x,
  //         +1 if this > x
};

// Implementation needs to cast x to the proper class.

// Any class that may appear in a container should
//  implement Comparable, so the container can support
//  sorting.
```

Comparison with C++

Java	C++
methods	virtual member functions
public/protected/private members	similar
static members	same
abstract methods	pure virtual member functions
`final` methods	no analogous feature
`interface`	pure virtual class with no data members
implementation of an interface	virtual inheritance

Simulating a first-class function with an object

A simple first-class function:

```
fun mkAdder nonlocal = (fn arg => arg + nonlocal)
```

The corresponding C++ class:

```
class Adder {
    int nonlocal;
public:
    Adder (int i) : nonlocal(i) { }
    int operator() (int arg) { return arg + nonlocal; }
};
```

`mkAdder 10` is roughly equivalent to `Adder(10)`.

First-class functions strike back

A simple unsuspecting object (in Java, for variety):

```
class Account {
   private float theBalance;
   private float theRate;

   Account (float b, float r) { theBalance = b;
                                theRate = r; }

   public void deposit (float x) {
     theBalance = theBalance + x;
   }
   public void compound () {
     theBalance = theBalance * (1.0 + rate);
   }
   public float balance () { return theBalance; }
}
```

First-class functions strike back, part 2

The corresponding first-class function:

```
(define (Account b r)
    (let ((theBalance b) (theRate r))
        (lambda (method)
            (case method
                ((deposit)
                    (lambda (x) (set! theBalance
                                      (+ theBalance x))))
                ((compound)
                    (set! theBalance (* theBalance
                                        (+ 1.0 theRate))))
                ((balance)
                    theBalance)))))
```

`new Account(100.0, 0.05)` is roughly equivalent to `(Account 100.0 0.05)`.

Comparing ML datatypes with inheritance

ML datatypes and OO inheritance organize data and routines in orthogonal ways:

	data variants	**data operations**
datatypes	all together/closed	scattered/open
classes	scattered/open	all together/closed

datatypes	easy to add new operations
	harder to add new variants
classes	easy to add new variants
	harder to add new operations

OOP Pitfalls: the circle and the ellipse

A couple of facts:

- In mathematics, an ellipse (from the Greek for absence) is a curve where the sum of the distances from any point on the curve to two fixed points is constant. The two fixed points are called foci (plural of focus).

  from http://en.wikipedia.org/wiki/Ellipse
- A circle is a special kind of ellipse, where the two foci are the same point.

If we need to model circles and ellipses using OOP, what happens if we have class `Circle` inherit from class `Ellipse`?

Circles and ellipses

```
class Ellipse {
  ...

  public move (double dx, double dy) { ... }

  public resize (double x, double y) { ... }
}

class Circle extends Ellipse {
  ...

  public resize (double x, double y) { ??? }
}
```

We can't implement a resize for `Circle` that lets us make it asymmetric!

Pitfalls: Array subclassing

In Java, if class B is a subclass of class A, then Java considers "array of B" to be a subclass of "array of A":

```
class A { ... }
class B extends A { ... }

B[] b = new B[5];
A[] a = b;          // allowed (a and b are now aliases)

a[1] = new A();    // Bzzzt!  (Type error)
```

The problem is that arrays are *mutable*; they allow us to replace an element with a different element.