CS 242

# Simula and Smalltalk

John Mitchell

## Simula 67

- First object-oriented language
- Designed for simulation
  - Later recognized as general-purpose prog language
- Extension of Algol 60
- Standardized as Simula (no "67") in 1977
- Inspiration to many later designers
  - Smalltalk
  - C++
  - …

## Brief history

- Norwegian Computing Center
  - Designers: Dahl, Myhrhaug, Nygaard
  - Simula-1 in 1966 (strictly a simulation language)
  - General language ideas
    - Influenced by Hoare's ideas on data types
    - Added classes and prefixing (subtyping) to Algol 60
  - Nygaard
    - Operations Research specialist and political activist
    - Wanted language to describe social and industrial systems
    - Allow "ordinary people" to understand political (?) changes
  - Dahl and Myhrhaug
    - Maintained concern for general programming

## Comparison to Algol 60

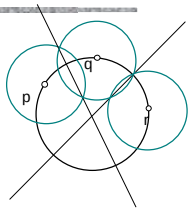
- Added features
  - class concept
  - reference variables (pointers to objects)
  - pass-by-reference
  - char, text, I/O
  - coroutines
- Removed
  - Changed default par passing from pass-by-name
  - some var initialization requirements
  - own (=C static) variables
  - string type (in favor of text type)

## Objects in Simula

- Class
  - A procedure that returns a pointer to its activation record
- Object
  - Activation record produced by call to a class
- Object access
  - Access any local variable or procedures using dot notation: object.
- Memory management
  - Objects are garbage collected
    - user destructors considered undesirable

## Example: Circles and lines

- Problem
  - Find the center and radius of the circle passing through three distinct points, p, q, and r
- Solution
  - Draw intersecting circles Cp, Cq around p,q and circles Cq', Cr around q, r (Picture assumes Cq = Cq')
  - Draw lines through circle intersections
  - The intersection of the lines is the center of the desired circle.
  - Error if the points are colinear.



## Approach in Simula

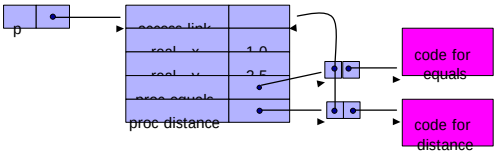
- Methodology
  - Represent points, lines, and circles as objects.
  - Equip objects with necessary operations.
- Operations
  - Point
    - equality(anotherPoint) : boolean
    - distance(anotherPoint) : real (needed to construct circles)
  - Line
    - parallelto(anotherLine) : boolean (to see if lines intersect)
    - meets(anotherLine) : REF(Point)
  - Circle
    - intersects(anotherCircle) : REF(Line)

## Simula Point Class

```
class Point(x,y); real x,y;                    formal p is pointer to Point
      begin
        boolean procedure equals(p); ref(Point) p;
          if p =/= none then
              equals := abs(x - p.x) + abs(y - p.y) < 0.00001
        real procedure distance(p); ref(Point) p;
          if p == none then error else
              distance := sqrt(( x - p.x )**2 + (y - p.y) ** 2);
end ***Point***

p :- new Point(1.0, 2.5);                      uninitialized ptr has
q :- new Point(2.0,3.5);                       value none
if p.distance(q) > 2 then ...                  pointer assignment
```

## Representation of objects




Object is represented by activation record with access link to find global variables according to static scoping

## Simula line class

```
class Line(a,b,c); real a,b,c;                 Local variables
    begin
      boolean procedure parallelto(l); ref(Line) l;
          if l =/= none then  parallelto := ...
      ref(Point) procedure meets(l); ref(Line) l;
          begin real t;
            if l =/= none and ~parallelto(l) then ...
          end;
      real d;   d := sqrt(a**2 + b**2);
      if d = 0.0 then error else
          begin
            d := 1/d;
            a := a*d;  b := b*d;  c := c*d;
          end;
  end *** Line***
```

line determined by ax+by+c=0

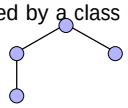
Procedures

Initialization: "normalize" a,b,c

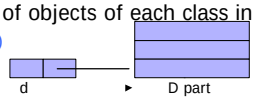
## Derived classes in Simula

- A class decl may be prefixed by a class name

  class A
  A class B
  A class C
  B class D



- An object of a "prefixed class" is the concatenation of objects of each class in prefix
  - d :- new D(...)




## Subtyping

- The type of an object is its class
- The type associated with a subclass is treated as a subtype of the type assoc with superclass
- Example:

```
class A(...);  ...
A class B(...); ...
ref (A) a :- new A(...)
ref (B) b :- new B(...)
a := b          /* legal since B is subclass of A */
...
b := a         /* also legal, but run-time test  */
```

## Main object-oriented features

- Classes
- Objects
- Inheritance ("class prefixing")
- Subtyping
- Virtual methods
  - A function can be redefined in subclass
- Inner
  - Combines code of superclass with code of subclass
- Inspect/Qua
  - run-time class/type tests

## Features absent from Simula 67

- Encapsulation
  - All data and functions accessible; no private, protected
- Self/Super mechanism of Smalltalk
  - But has an expression this⟨class⟩ to refer to object itself, regarded as object of type ⟨class⟩. Not clear how powerful this is...
- Class variables
  - But can have global variables
- Exceptions
  - Not an OO feature anyway ...

## Simula Summary

- Class
  - "procedure" that returns ptr to activation record
  - initialization code always run as procedure body
- Objects: closure created by a class
- Encapsulation
  - protected and private not recognized in 1967
  - added later and used as basis for C++
- Subtyping: determined by class hierarchy
- Inheritance: provided by class prefixing

## Smalltalk

- Major language that popularized objects
- Developed at Xerox PARC
  - Smalltalk-76, Smalltalk-80 were important versions
- Object metaphor extended and refined
  - Used some ideas from Simula, but very different lang
  - Everything is an object, even a class
  - All operations are "messages to objects"
  - Very flexible and powerful language
    - Similar to "everything is a list" in Lisp, but more so
    - Example: object can detect that it has received a message it does not understand, can try to figure out how to respond.

## Motivating application: Dynabook

- Concept developed by Alan Kay (now Disney?)
- Small portable computer
  - Revolutionary idea in early 1970's
    - At the time, a *minicomputer* was shared by 10 people, stored in a machine room.
  - What would you compute on an airplane?
- Influence on Smalltalk
  - Language intended to be programming language and operating system interface
  - Intended for "non-programmer"
  - Syntax presented by language-specific editor

## Smalltalk language terminology

- Object — Instance of some class
- Class — Defines behavior of its objects
- Selector — Name of a message
- Message — Selector together with parameter values
- Method — Code used by a class to respond to message
- Instance variable — Data stored in object
- Subclass — Class defined by giving incremental modifications to some superclass

## Example: Point class

- Class definition written in tabular form

| | |
|---|---|
| class name | Point |
| super class | Object |
| class var | pi |
| instance var | x y |
| class messages and methods | |
| ⟨...names and code for methods...⟩ | |
| instance messages and methods | |
| ⟨...names and code for methods...⟩ | |

## Class messages and methods

Three class methods

```
newX:xvalue Y:yvalue | |
^ self new x: xvalue
          y: yvalue

newOrigin | |
^ self new x: 0
          y: 0

initialize | |
pi <- 3.14159
```

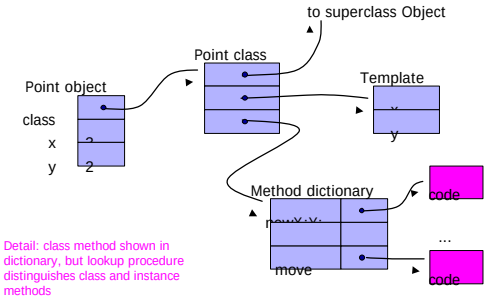
Explanation

- selector is mix-fix newX:Y:
  e.g, Point newX:3 Y:2
- symbol ^ marks return value
- new is method in all classes, inherited from Object
- | | marks scope for local decl
- initialize method sets pi, called automatically
- <- is syntax for assignment

## Instance messages and methods

| Five instance methods | Explanation |
|---|---|
| x: xcoord y: ycoord \| \| | set x,y coordinates, |
| x <- xcoord | e.g, pt x:5 y:3 |
| y <- ycoord | |
| moveDx: dx Dy: dy \| \| | move point by given amount |
| x <- dx + x | |
| y <- dy + y | |
| x \| \| ^x | return hidden inst var x |
| y \| \| ^y | return hidden inst var y |
| draw \| \| | draw point on screen |
| ⟨...code to draw point...⟩ | |

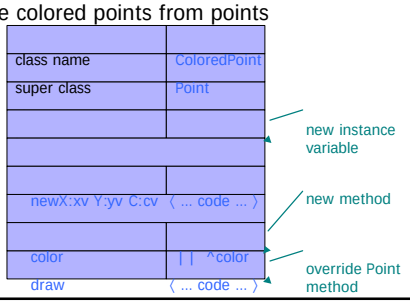
## Run-time representation of point



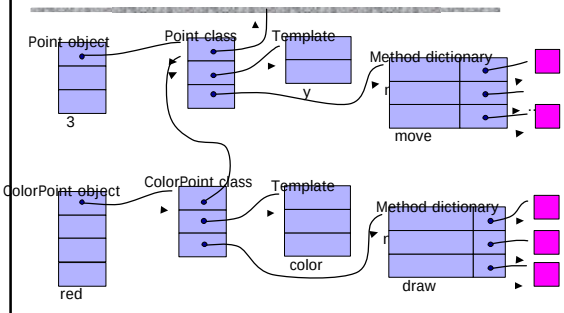

Detail: class method shown in dictionary, but lookup procedure distinguishes class and instance methods

## Inheritance

- Define colored points from points




## Run-time representation




This is a schematic diagram meant to illustrate the main idea. Actual implementations may differ.

## Encapsulation in Smalltalk

- Methods are public
- Instance variables are hidden
  - Not visible to other objects
    - pt x  is not allowed unless x is a method
  - But may be manipulated by subclass methods
    - This limits ability to establish invariants
    - Example:
      - Superclass maintains sorted list of messages with some selector, say insert
      - Subclass may access this list directly, rearrange order

## Object type

- Each object has interface
  - Set of instance methods declared in class
  - Example:
    Point  { x:y:, moveDx:Dy:, x, y, draw}
    ColorPoint  { x:y:, moveDx:Dy:, x, y, color, draw}
  - This is a form of type
    Names of methods, does not include type/protocol of arguments
- Object expression and type
  - Send message to object
    p draw  p x:3 y:4
    q color  q moveDx: 5 Dy: 2
  - Expression OK if message is in interface

## Subtyping

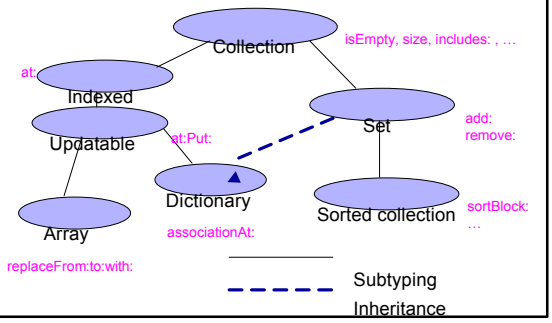
- Relation between interfaces
  - Suppose expression makes sense
    p msg:pars  -- OK if msg is in interface of p
  - Replace p by q if interface of q contains interface of p
- Subtyping
  - If interface is superset, then a subtype
  - Example: ColorPoint subtype of Point
  - Sometimes called “conformance”

Can extend to more detailed interfaces that include types of parameters

## Subtyping and Inheritance

- Subtyping is implicit
  - Not a part of the programming language
  - Important aspect of how systems are built
- Inheritance is explicit
  - Used to implement systems
  - No forced relationship to subtyping

## Collection Hierarchy




## Smalltalk Flexibility

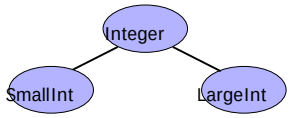
- Measure of PL expressiveness:
  - Can constructs of the language be defined in the language itself?
  - Examples:
    - Lisp cond:  Lisp allows user-defined special forms
    - ML datatype: sufficient to define polymorphic lists, equivalent to built-in list type
    - ML overloading: limitation, since not available to programmer
    - C/C++: ???
- Smalltalk is expressive in this sense
  - Many constructs that would be “primitives” other are definable in Smalltalk
  - Example: Booleans and Blocks

## Smalltalk booleans and blocks

- Boolean value is object with ifTrue:ifFalse:
  - Class boolean with subclasses True and False
  - True ifTrue:B1 ifFalse:B2 executes B1
  - False ifTrue:B1 ifFalse:B2 executes B2
- Example expression

  i < j  ifTrue: [i add 1] ifFalse: [j subtract 1]
  - i < j is boolean expression, produces boolean object
  - arg's are *blocks*, objects with execute methods
- Since booleans and blocks are very common
  - Optimization of boolean
  - Special syntax for blocks

## Self and Super




```
Factorial |   |
    self <= 1
        ifTrue: [^1]
        ifFalse: [^(self-1) factorial * self ]
```

This method can be implemented in Integer, and works even if SmallInt and LargeInt are represented differently. C++ and Java type systems can't really cope with this.

## Ingalls' test

- Dan Ingalls: principal designer Smalltalk system
  - Grace Murray Hopper award for Smalltalk and Bitmap graphics work at Xerox PARC
  - 1987 ACM Software Systems Award with Kay, Goldberg
- Proposed test for "object oriented"
  - Can you define a new kind of integer, put your new integers into rectangles (which are already part of the window system), ask the system to blacken a rectangle, and have everything work?
  - Smalltalk passes, C++ fails this test

## Smalltalk integer operations

- Integer expression
  - x plus: 1 times: 3 plus: (y plus: 1)  print
- Properties
  - All operations are executed by sending messages
  - If x is from some "new" kind of integer, expression makes sense as long as x has plus, times, print methods.

Actually, compiler does some optimization. But will revert to this if x is not built-in integer.

## Costs and benefits of "true OO"

- Why is property of Ingalls test useful?
  - Everything is an object
  - All objects are accessed only through interface
  - Makes programs extensible
- What is implementation cost?
  - Every integer operation involves method call
    - Unless optimizing compiler can recognize many cases
  - Is this worth it?
    - One application where it seems useful ?
    - One application where it seems too costly?
    - Are there other issues? Security?  (wait for Java final classes…)

## Smalltalk Summary

- Class
  - creates objects that share methods
  - pointers to template, dictionary, parent class
- Objects: created by a class, contains instance variables
- Encapsulation
  - methods public, instance variables hidden
- Subtyping: implicit, no static type system
- Inheritance: subclasses, self, super

  Single inheritance in Smalltalk-76, Smalltalk-80