CS 242

Simula and Smalltalk

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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

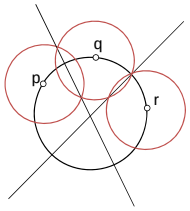
- Added features
  - class concept
  - reference variables (pointers to objects)
  - pass-by-reference
  - char, text, I/O
  - coroutines
- Removed
  - Changed default par passing from pass-by-name
  - some var initialization requirements
  - own (=C static) variables
  - string type (in favor of text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

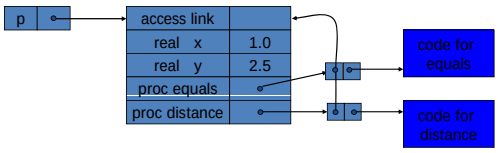
- Methodology
  - Represent points, lines, and circles as objects.
  - Equip objects with necessary operations.
- Operations
  - Point
    equality(anotherPoint) : boolean
    distance(anotherPoint) : real (needed to construct circles)
  - Line
    parallelto(anotherLine) : boolean (to see if lines intersect)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

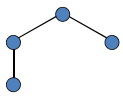
line determined by ax+by+c=0

Procedures

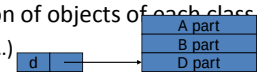
Initialization: "normalize" a,b,c

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 fundamentally an OO feature ...

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
- 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

```
x: xcoord y: ycoord | |
    x <- xcoord
    y <- ycoord
moveDx: dx Dy: dy | |
    x <- dx + x
    y <- dy + y
x | | ^x
y | | ^y
draw | |
    ⟨...code to draw point...⟩
```

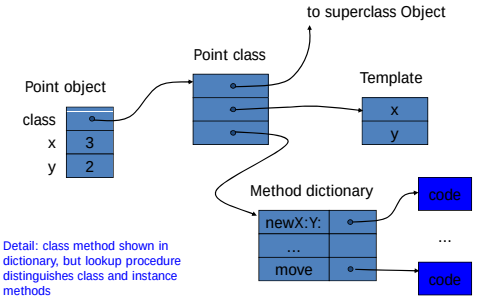
Explanation

set x,y coordinates,
e.g, pt x:5 y:3

move point by given amount

return hidden inst var x
return hidden inst var y
draw point on screen

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

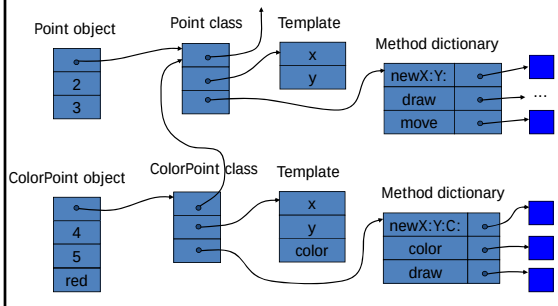
class name	ColorPoint
super class	Point
class var	
instance var	color
class messages and methods	
newX:xv Y:yv C:cv	⟨ ... code ... ⟩
instance messages and methods	
color	| | ^color
draw	⟨ ... code ... ⟩

new instance variable

new method

override Point method

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 types

- 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

Subtyping

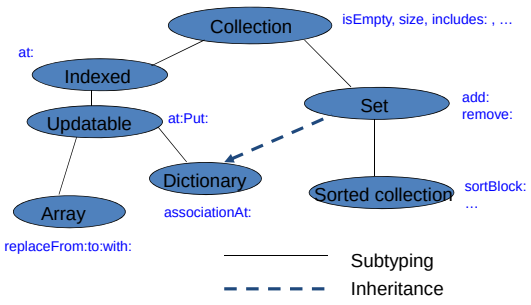
- Relation between interfaces
  - Suppose expression makes sense

    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”

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

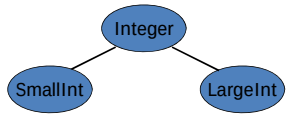
- Measure of PL expressiveness:
  - Can constructs of the language be defined in the language itself?
  - Examples:
    - Lisp cond: Lisp allows user-defined special forms
    - ML datatype: sufficient to define polymorphic lists, equivalent to built-in list type
    - ML overloading: limitation, since not available to programmer
    - C/C++: ???
- Smalltalk is expressive in this sense

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

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?

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

Ruby www.ruby-lang.org

- Ruby is a “complete, full, pure object oriented language”
  - All data in Ruby are objects, in the sense of Smalltalk
  - Example: the number 1 is an instance of class Fixnum
- Very flexible
  - Can add methods to a class, or even to instance during runtime
  - Closures
  - Automatic small integer (Fixnum) large integer (Bignum) conversion
- Single inheritance only
  - Ruby features single inheritance only, *on purpose*
  - Modules are collections of methods
    - A class can import a module and gets all its methods

Example Ruby class

```
class Song
  @@plays = 0
  def initialize(name, artist, duration)
    @name     = name
    @artist   = artist
    @duration = duration
    @plays    = 0
  end
  def play
    @plays += 1
    @@plays += 1
    "This  song: #@plays plays. Total #@@plays plays."
  end
end
```

see http://www.rubycentral.com/book/