Chapter 11

Categories of languages that support OOP:

1. **OOP support is added to an existing language**
   - C++ (also supports procedural and data-oriented programming)
   - Ada 95 (also supports procedural and data-oriented programming)
   - CLOS (also supports functional programming)
   - Scheme (also supports functional programming)

2. **Support OOP, but have the same appearance and use the basic structure of earlier imperative languages**
   - Eiffel (not based directly on any previous language)
   - Java (based on C++)

3. Pure OOP languages
   - Smalltalk
Chapter 11

Paradigm Evolution

1. Procedural - 1950s-1970s (procedural abstraction)

2. Data-Oriented - early 1980s (data-oriented)

3. OOP - late 1980s (Inheritance and dynamic binding)

Origins of Inheritance

Observations of the mid-late 1980s:

- Productivity increases can come from reuse
- ADTs are difficult to reuse--never quite right
- All ADTs are independent and at the same level

Inheritance solves both--reuse ADTs after minor changes and define classes in a hierarchy
Chapter 11

OOP Definitions:

- ADTs are called *classes*
- Class instances are called *objects*
- A class that inherits is a *derived class* or a *subclass*
- The class from which another class inherits is a *parent class* or *superclass*
- Subprograms that define operations on objects are called *methods*
- The entire collection of methods of an object is called its *message protocol* or *message interface*
- Messages have two parts--a method name and the destination object
- In the simplest case, a class inherits all of the entities of its parent
Chapter 11

- Inheritance can be complicated by access controls to encapsulated entities
  - A class can hide entities from its subclasses
  - A class can hide entities from its clients

- Besides inheriting methods as is, a class can modify an inherited method
  - The new one overrides the inherited one
  - The method in the parent is overridden

- There are two kinds of variables in a class:
  1. Class variables - one/class
  2. Instance variables - one/object

- There are two kinds of methods in a class:
  1. Class methods - messages to the class
  2. Instance methods - messages to objects

- Single vs. Multiple Inheritance
Chapter 11

- Disadvantage of inheritance for reuse:
  - Creates interdependencies among classes that complicate maintenance

Polymorphism in OOPLs

- A polymorphic variable can be defined in a class that is able to reference (or point to) objects of the class and objects of any of its descendants

- When a class hierarchy includes classes that override methods and such methods are called through a polymorphic variable, the binding to the correct method MUST be dynamic

- This polymorphism simplifies the addition of new methods

- A virtual method is one that does not include a definition (it only defines a protocol)

- A virtual class is one that includes at least one virtual method

- A virtual class cannot be instantiated
Chapter 11

Design Issues for OOPLs

1. *The Exclusivity of Objects*

   a. Everything is an object
      
      *advantage* - elegance and purity
      
      *disadvantage* - slow operations on simple objects (e.g., float)

   b. Add objects to a complete typing system
      
      *Advantage* - fast operations on simple objects
      
      *Disadvantage* - results in a confusing type system

   c. Include an imperative-style typing system for primitives but make everything else objects
      
      *Advantage* - fast operations on simple objects and a relatively small typing system
      
      *Disadvantage* - still some confusion because of the two type systems

2. *Are Subclasses Subtypes?*

   - Does an is-a relationship hold between a parent class object and an object of the subclass?
Chapter 11

3. Implementation and Interface Inheritance

- If only the interface of the parent class is visible to the subclass, it is interface inheritance

  *Disadvantage* - can result in inefficiencies

- If both the interface and the implementation of the parent class is visible to the subclass, it is implementation inheritance

  *Disadvantage* - changes to the parent class require recompilation of subclasses, and sometimes even modification of subclasses

4. Type Checking and Polymorphism

- Polymorphism may require dynamic type checking of parameters and the return value
  - Dynamic type checking is costly and delays error detection
- If overriding methods are restricted to having the same parameter types and return type, the checking can be static
Chapter 11

5. Single and Multiple Inheritance

- Disadvantage of multiple inheritance:
  - Language and implementation complexity
  - Potential inefficiency - dynamic binding costs more with multiple inheritance (but not much)

- Advantage:
  - Sometimes it is extremely convenient and valuable

6. Allocation and Deallocation of Objects

- From where are objects allocated?
  - If they all live in the heap, references to them are uniform

- Is deallocation explicit or implicit?
Chapter 11

7. Dynamic and Static Binding

- Should ALL binding of messages to methods be dynamic?
Chapter 11

Overview of Smalltalk

- *Smalltalk is a pure OOP language*
  - Everything is an object
  - All computation is through objects sending messages to objects
  - It adopts none of the appearance of imperative languages

- *The Smalltalk Environment*
  - The first complete GUI system
  - A complete system for software development
  - All of the system source code is available to the user, who can modify it if he/she wants

Introduction to Smalltalk

- *Expressions*
  - Four kinds:
    1. Literals (numbers, strings, and keywords)
    2. Variable names (all variables are references)
    3. Message expressions (see below)
    4. Block expressions (see below)
Chapter 11

- Message expressions

- Two parts: the receiver object and the message itself
- The message part specifies the method and possibly some parameters
- Replies to messages are objects

- Messages can be of three forms:
  1. Unary (no parameters)
     e.g., myAngle sin
     (sends a message to the sin method of the myAngle object)
  2. Binary (one parameter, an object)
     e.g., 12 + 17
     (sends the message “+ 17” to the object 12; the object parameter is “17” and the method is “+”)
  3. Keyword (use keywords to organize the parameters)
     e.g., myArray at: 1 put: 5
     (sends the objects “1” and “5” to the at:put: method of the object myArray)

- Multiple messages to the same object can be strung together, separated by semicolons
Chapter 11

Methods

- General form:
  message_pattern [ | temps | ] statements

- A message pattern is like the formal parameters of a subprogram
  - For a unary message, it is just the name
  - For others, it lists keywords and formal names
- temps are just names--Smalltalk is typeless!

Assignments

- Simplest Form:
  name1 <- name2

- It is simply a pointer assignment

- RHS can be a message expression
  e.g., index <- index + 1

Blocks

- A sequence of statements, separated by periods, delimited by brackets
  e.g.,
  [index <- index + 1. sum <- sum + index]
Chapter 11

Blocks (continued)

- A block specifies something, but doesn’t do it
- To request the execution of a block, send it the unary message, value
  e.g., [...] value

- If a block is assigned to a variable, it is evaluated by sending value to that variable
  e.g.,
  ```ruby
  addIndex <- [sum <- sum + index]
  ...
  addIndex value
  ```

- Blocks can have parameters, as in
  ```ruby
  [:x :y | statements]
  ```

- If a block contains a relational expression, it returns a Boolean object, true or false

Iteration

- The objects true and false have methods for building control constructs

- The method WhileTrue: from Block is used for pretest logical loops. It is defined for all blocks that return Boolean objects.
Chapter 11

Iteration (continued)

e.g.,

\[
\begin{align*}
\text{[count} & \leq 20] \\
\text{whileTrue} & \text{ [sum} \leftarrow \text{sum} + \text{count.} \\
& \text{count} \leftarrow \text{count} + 1]
\end{align*}
\]

- \text{timesRepeat: is defined for integers and can be used to build counting loops}

e.g.,

\[
x\text{Cube} \leftarrow 1. \\
3 \text{timesRepeat: [xCube} \leftarrow \text{xCube} \times x]
\]

Selection

- The Boolean objects have the method \text{ifTrue:ifFalse:}, which can be used to build selection

e.g.,

\[
\begin{align*}
\text{total} & = 0 \\
\text{ifTrue: [...]} \\
\text{ifFalse: [...]}
\end{align*}
\]
Chapter 11

Large-Scale Features of Smalltalk

- **Type Checking and Polymorphism**

  - All bindings of messages to methods is dynamic

    - The process is to search the object to which the message is sent for the method; if not found, search the superclass, etc.

  - Because all variables are typeless, methods are all polymorphic

- **Inheritance**

  - All subclasses are subtypes (nothing can be hidden)

  - All inheritance is implementation inheritance

  - No multiple inheritance

  - Methods can be redefined, but the two are not related
Chapter 11

C++

- **General Characteristics:**
  - Mixed typing system
  - Constructors and destructors
  - Elaborate access controls to class entities

- **Inheritance**

  - A class need not be subclasses of any class

  - *Access controls for members are*
    1. Private (visible only in the class and friends)
    2. Public (visible in subclasses and clients)
    3. Protected (visible in the class and in subclasses)

  - In addition, the subclassing process can be declared with access controls, which define potential changes in access by subclasses

- Multiple inheritance is supported
Chapter 11

Inheritance (continued)

- **Dynamic Binding**
  - A method can be defined to be virtual, which means that they can be called through polymorphic variables and dynamically bound to messages
  - A pure virtual function has no definition at all
  - A class that has at least one pure virtual function is an abstract class

- **Evaluation**
  - C++ provides extensive access control (unlike Smalltalk)
  - C++ provides multiple inheritance
  - In C++, the programmer must decide at design time which methods will be statically bound and which must be dynamically bound
    - Static binding is faster!
  - Smalltalk type checking is dynamic (flexible, but somewhat unsafe)
Java

- **General Characteristics**

  - All data are objects except the primitive types

  - All primitive types have wrapper classes that store one data value

  - All objects are heap-dynamic, are referenced through reference variables, and most are allocated with `new`

- **Inheritance**

  - Single inheritance only, but there is an abstract class category that provides some of the benefits of multiple inheritance (interface)

  - An interface can include only method declarations and named constants

    e.g.,
    
    ```java
    public class Clock extends Applet
    implements Runnable
    ```

- **Methods can be final (cannot be overriden)**
Chapter 11

- Dynamic Binding

- In Java, all messages are dynamically bound to methods, unless the method is final

- Encapsulation

- Two constructs, classes and packages

- Packages provide a container for classes that are related

- Entities defined without an scope (access) modifier have package scope, which makes them visible throughout the package in which they are defined

- Every class in a package is a friend to the package scope entities elsewhere in the package
Chapter 11

Ada 95

- **General Characteristics**
  - OOP was one of the most important extensions to Ada 83
  - Encapsulation container is a package that defines a tagged type
  - A tagged type is one in which every object includes a tag to indicate during execution its type
  - Tagged types can be either private types or records
  - No constructors or destructors are implicitly called

- **Inheritance**
  - Subclasses are derived from tagged types
  - New entities in a subclass are added in a record
Example:

with PERSON_PKG; use PERSON_PKG;
package STUDENT_PKG is
    type STUDENT is new PERSON with
        record
            GRADE_POINT_AVERAGE : FLOAT;
            GRADE_LEVEL : INTEGER;
        end record;
    procedure DISPLAY (ST: in STUDENT);
end STUDENT_PKG;

- DISPLAY is being overridden from PERSON_PKG

- All subclasses are subtypes

- Single inheritance only, except through generics

- **Dynamic Binding**

- Dynamic binding is done using polymorphic variables called classwide types
e.g., for the tagged type PERSON, the classwide type is PERSON'class

- Other bindings are static

- Any method may be dynamically bound
Chapter 11

Eiffel

- General Characteristics
  - Has primitive types and objects
  - All objects get three operations, copy, clone, and equal
  - Methods are called *routines*
  - Instance variables are called *attributes*
  - The routines and attributes of a class are together called its *features*
  - Object creation is done with an operator (!!)
  - Constructors are defined in a creation clause, and are explicitly called in the statement in which an object is created

- *Inheritance*

  - The parent of a class is specified with the inherit clause
Chapter 11

- **Access control**

  - feature clauses specify access control to the entities defined in them

  - Without a modifier, the entities in a feature clause are visible to both subclasses and clients

  - With the child modifier, entities are hidden from clients but are visible to subclasses

  - With the none modifier, entities are hidden from both clients and subclasses

  - Inherited features can be hidden from subclasses with undefine

  - Abstract classes can be defined by including the deferred modifier on the class definition

- **Dynamic Binding**

  - Nearly all message binding is dynamic

  - An overriding method must have parameters that are assignment compatible with those of the overridden method
Chapter 11

- *Dynamic Binding* (continued)

- All overriding features must be defined in a redefine clause

- Access to overridden features is possible by putting their names in a rename clause

- *Evaluation*

  - Similar to Java in that procedural programming is not supported and nearly all message binding is dynamic

  - Elegant and clean design of support for OOP

Implementing OO Constructs

- Class instance records (CIRs) store the state of an object

- If a class has a parent, the subclass instance variables are added to the parent CIR

- Virtual Method Tables (VMTs) are used for dynamic binding