Data Abstraction and Object Orientation

Data Abstractions

- Scopes and lifetime
  - Global variables (introduced by Basic)
    - Lifetime and scope spans program execution
  - Local variables (introduced by Fortran)
    - Lifetime and scope limited to execution of subroutine
  - Nested scopes (Algol 60)
    - Allows subroutines or blocks to themselves be local
  - Static variables (Fortran)
    - Lifetime spans execution, names visible in a single scope
  - Modules (Modula-2)
    - Allow a collection of subroutines to share a set of static variables
  - Module types (Euclid)
    - Allow instantiation of multiple instances of a given abstraction
  - Classes (Smalltalk, C++, Java)
    - Allow definition of families of related abstractions

Why abstractions?

- Reduce conceptual load
  - Hide implementation details
- Independence among program components
  - Replacement of pieces without rewriting others
  - Organizational compartmentalization
- Fault containment
  - Enforce division of labor
  - Prevent access to things you shouldn't see

Object-Oriented Programming

- Fundamental concepts
  - Encapsulation
  - Inheritance
  - Dynamic method binding
- Class – module as the abstract type including data and method definition
- Object – instance of a class

Encapsulation

- Allows reasoning at the level of the interface
- Namespace (C++) or packages (Java)
  - Modules that span multiple files
  - Collection of objects (subroutines, types, variables) visible to each other but visible to the outside only if explicitly exported
  - Class definitions visible only within module

Initialization and Finalization

- Constructors and destructors
  - Storage allocation and deallocation
  - Call base constructor before derived class constructor

Visibility Rules

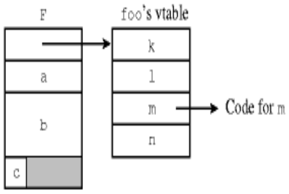
- Parts of an object declaration/definition (e.g., C++)
  - – Public
    - Accessible to users of the class
  - – Private
    - Accessible to members of this class
  - – Protected
    - Accessible to members of this or derived classes
- Derived classes can restrict visibility of members of a base class in C++ (but not in Java)

Implementation of Classes

- Dynamic method binding
  - – Virtual methods to dispatch appropriate implementation at run time (dynamic)
  - – Abstract classes – contain virtual methods with no body
  - – Virtual method table (vtable)
    - Array whose ith entry indicates the address of the code for the object's ith virtual method
    - First field of record of each object contains address of vtable, shared by all objects of a given class
- Static method binding – version called based on type of the variable or reference being used rather than class to which object referred to belongs
- Reflection – mechanism by which type information can be obtained at run time

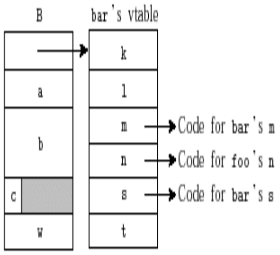
Virtual Method Table (vtable)

```
class foo {
    int a;
    double b;
    char c;
public:
    virtual void k ( ...
    virtual int l ( ...
    virtual void m ();
    virtual double n( ...
    ...
} F;
```



Dynamic Method Binding

```
class bar : public foo {
    int w;
public:
    void m ();  //override
    virtual double s ( ...
    virtual char *t ( ...
    ...
} B;
```



Generics

- Dynamic method binding introduces polymorphism
- Base class methods return references of base class type
- Type-specific operations?Use generics

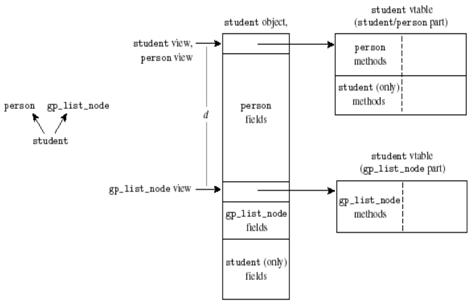
```
template<class V>
class list_node {
    list_node<V> *prev;
public:
    V val;
…

typedef list_node<int> int_list_node;
…
int_list_node* first_int;
```

Inheritance

- Multiple inheritance - Inherit from more than one base class
  - – E.g.,

    class student : public person, public gp_list_node { …
  - – Replicated vs. shared inheritance when deriving from the same base
- Mix-in inheritance
  - – Java – base class composed entirely of abstract methods (an interface)
  - – Inherit from one real base class and an arbitrary number of interfaces
  - – Facilitates code reuse through polymorphism

Multiple Inheritance


student object,
student vtable
(student/person part)
student view,
person view
person
methods
student (only)
methods
person   gp_list_node
student
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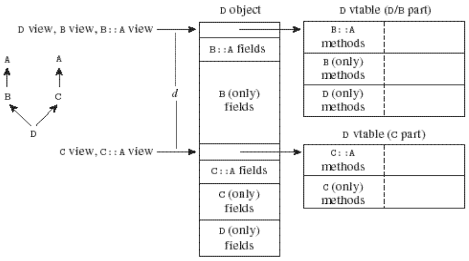
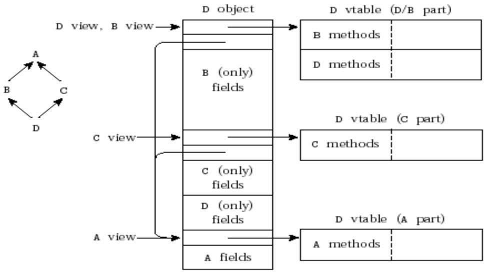
person
fields
student vtable
(gp_list_node part)
gp_list_node view
gp_list_node
methods
gp_list_node
fields
student (only)
fields

Replicated Multiple Inheritance


D object
D vtable (D/B part)
D view, B view, B::A view
B::A
methods
B::A fields
B (only)
methods
A   A
B   C
D
d
B (only)
fields
D (only)
methods
D vtable (C part)
C view, C::A view
C::A
methods
C::A fields
C (only)
methods
C (only)
fields
D (only)
fields

Shared Multiple Inheritance


D object
D vtable (D/B part)
D view, B view
B methods
D methods
A
B   C
D
B (only)
fields
D vtable (C part)
C view
C methods
C (only)
fields
D (only)
fields
D vtable (A part)
A view
A methods
A fields