Data Abstraction and OO

Textbook: Chapter 9 (incl. CD material)

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Data Abstraction and OO

- **Modules or Objects/Classes**
- **Reduces conceptual load by modularizing code**
- **Contains faults to small parts of code**
- **Makes program components more independent**

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Why OO?

- **Groups data with code**
  - **Data is isolated in private object fields**
  - **Methods operating on the data are bundled with the data in classes**
  - **Other code can't mess with the data**
  - **Classes can be easily added or removed from the code**

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Programming Style

- C++

```
class C { … public: virtual int foo() { … }}
class D :public C { virtual int foo() { … }}
class E :public C { virtual int foo() { … }}
```

- C

```
int foo(C * obj) {
  if (obj is a D)
    ...     // code from D::foo()
  else if (obj is an E)
    ...     // code from E::foo()
  else
    ...     // code from C::foo()
}
```

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OO vs. ADT/Functional Style

- Object-oriented programming
  - Extending a data structure is easy
  - Adding new code to an existing data structure is hard
- ADT/Functional/Imperative Style
  - Adding new code is easy
  - Extending a data structure is hard

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Object-Oriented Programming

- User-defined types
  - Classes
- Encapsulation
  - Private fields
- Subtype polymorphism
  - Inheritance
  - Structural subtyping
- Code reuse
  - Inheritance

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What is a Type?

- Built-in types: `int`, `char`, etc.
- Class types
- Interface types (in Java)

- Think of a type as a set of values
  - `int` = -2^31 .. 2^31-1
  - `C` = set of instances of class C or any subclass of C

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Subtyping

- C is a subtype of B (C <: B)
- or a C object *isa* B object
- or a C object can be used wherever a B object is expected
- or C is more specific than B

- The set of C instances is a subset of the set of B instances

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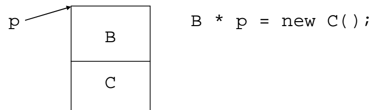
Implementation of Subtyping

- The layout of a C object includes a B object



- If (virtual) methods are overridden, we need to select the appropriate method at run time

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Selection of Virtual Methods

```
class B {
  public int foo () { return 0; }
}

class C extends B {
  public int foo () { return 1; }
}

B obj = new C();
int i = obj.foo ();  /* executes C.foo */
```

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Method Selection Algorithm

- **Method call**
  ```
  C * p = new D();
  p->foo(42, p)
  ```
- **Compile-time overload resolution**
  - **Find the receiver's (`p`'s) static type (`C`)**
  - **Inside `C` find an appropriate method for the static types of the arguments (`(int,C)`)**
- **Run-time virtual method dispatch**
  - **Look up the code for the method signature `foo(int,C)` in the virtual function table**

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Implementation of Method Dispatch

- **Conceptually: an object contains a list of pointers to its methods**
- **C++: the object contains a pointer to the virtual function table**
- **Java: an object pointer consists of a pointer to the object and a pointer to the dispatch table**

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Other Design Issues

- **Single or multiple inheritance**
  - **C++:** `class C : public A, public B {};`
  - **Java:** `class C extends B { }`
- **C++-style virtual inheritance**
  - `class C : public virtual A { };`
  - **allows objects to share a common part from multiple base classes**

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Other Design Issues

- **Single dispatch or multimethods**
  - **single dispatch: virtual functions**
  - **multiple dispatch: run-time overloading**
- **Function call or message passing**
  - **C++/Java:** `o.foo()`
  - **Smalltalk:** `o foo`
- **Typed or untyped**
- **Interface types vs. abstract classes**

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Multiple Inheritance

```
class A { int x; };
class B {
  int y;
public:
  virtual int foo (int);
};
class C : public A, public B {
  int z;
public:
  virtual int foo (int);
  virtual void bar (int);
};
```

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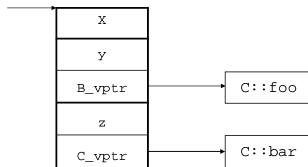
Implementation of Multiple Inheritance

- Concatenate all the pieces in layout
- Multiple vtables per object (C++)



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Implementation of Multiple Inheritance

- Adjust `this' pointer

```
B * p = new C;
int i = p->foo(42);
```

- is translated to

```
int i = ((p->B_vptr)[1].fn)
          (p+(p->B_vptr)[1].delta, 42)
```

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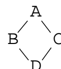
Virtual Inheritance

- Sharing of common part

```
class A;
class B : public virtual A;
class C : public virtual A;
class D : public B, public C;
```



- Implementation: B and C parts contain pointers to common A part

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Multimethods

- Instead of run-time method selection based on receiver (virtual in C++)
- Run-time method selection based on all arguments
- Like overloading but with method selection at run time
- Allows different program structure
- Languages: CLOS, Cecil, Brew

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Multimethod Implementation

- Generic functions dispatch using an n-dimensional table lookup
- Example

```
int foo (C);
int foo (D);
C p = new D();
int i = foo(p);      // calls foo(D)
```

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Function Call vs. Message Passing

- Function call syntax (C++)

```
p.foo(5);
p->foo(5);
```

- Message passing syntax (SmallTalk)

```
p foo 5.
6 * 7.
someArray at: 1 put: 5.
x = 0 ifTrue: [y <- 1]
      ifFalse: [y <- 2].
```

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Typed vs. Untyped

- **Statically typed (C++, Java, etc.)**
  - **no `message not understood' errors at run time**
  - **more efficient dispatch since layout of dispatch table is known**
- **Untyped (SmallTalk, CLOS, Cecil)**
  - **more flexibility**
  - **try to infer types for optimizing dispatch**

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Abstract Classes

```
class A {
public:
  virtual int foo () = 0;
};
class C : public A { /* ... */ }
```

- **Defines type**
- **Implementation is supplied in subclass**

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Interface Types

```
interface I {
  int foo ();
}
class C implements I { /* ... */ }
```

- **Separation of interface and implementation**
- **Cleaner design of type hierarchies**

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Structural Subtyping or Retroactive Abstraction

```
class C { public int foo () { ... } }
interface I {
  int foo ();
}
```

- **Structural Subtyping**

```
I p = new C();
```

- **Retroactive Abstraction**

```
class C implements I;
I p = new C();
```

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Signatures in G++

```
signature I {
  int foo ();
};
class C { public: int foo (); };
I * p = new C;
```

- **Implemented in G++ Versions 2.6-2.8**
- **Use `-fhandle-signatures' option**

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