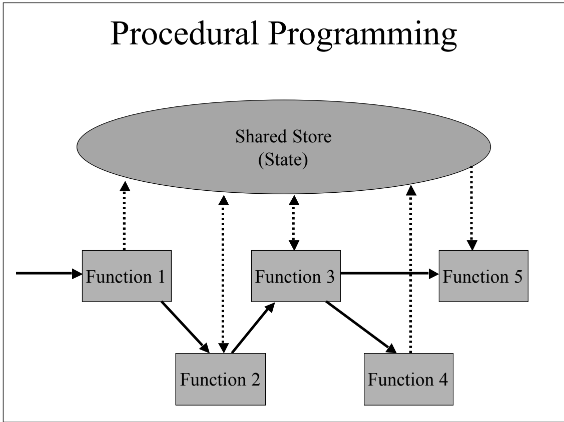
Imperative Programming Paradigm

Procedural Programming

Imperative/Procedural Paradigm

- The imperative paradigm is characterized by the finite state machine computational model.
- The imperative programming paradigm assumes that the program maintains a modifiable store.
- By changing the values of variables we alter what is stored, thus record state changes.
- Computations are performed through a sequence of steps specified by a list of commands.
- When imperative programming is combined with subprograms, it is called procedural programming.

Procedural Programming



Procedural Programming (2)

- The model does not scale well and large programs that use this model are difficult to maintain.
- It is difficult to find which functions are effected when the structure of the shared store is changed in any way.
- It is difficult to find relationships between functions that communicate indirectly through the shared store.

Modules

- One solution is to divide a program into units of separately compiled components called modules.
- Most procedural languages have some mechanism for creating modules.
- Each module has its own store which is shared internally.
- A module is encapsulated by a wall through which identifiers are invisible unless explicitly declared part of the modules interface.
- Modules are less powerful than abstract data types because they cannot be instantiated.

Object-Oriented Programming

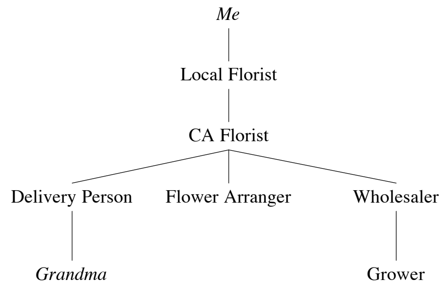
Topics

- Object-oriented thinking
  - Agents, messages, responsibility
- Abstract data types
- Inheritance
- Polymorphism
- Late binding

Object-Oriented Thinking

- Problem: How to get flowers to Grandma in California?
- Procedural solution:
  - 1. Plant flowers
  - 2. Water flowers
  - 3. Pick flowers
  - 4. Drive to CA
- Object-oriented solution:
  - 1. Call local florist

Agents and Responsibilities



Narrowing the Semantic Gap

- The power of metaphor
  - Thinking about problems in terms of slots and values doesn't provide much insight into how a program should be structured.
  - Thinking in terms of behaviors and responsibilities of agents, brings to mind a wealth of intuition, ideas, and understanding from everyday experience.
- Computation as simulation
  - Define a set of entities and how they interact, then set the system in motion.
- Programming by delegation
  - Object-oriented programmers think first about passing the buck.

Responsibility and Independence

Ask not what you can do to *your data structures, but what your data structures can do* for *you.*

- Timothy Budd

Abstract Data Types

- **Quiz**: What is the IEEE754 standard 32-bit representation of the floating point decimal number -5.125 ?
- When (for example) a float is incremented, its representation is changed. How is it possible for a programmer to accomplish the change without knowing the underlying representation?

Abstract Data Types (2)

- **float** is an ADT, defined in terms of a set of *operations* (+, -, ++, etc.) not its internal representation.

float x, y; // x and y are *instances* of type float

- Objects are instances of programmer defined ADT's.

Abstract Data Types (3)

Example: Stack ADT defined in terms of operations push, pop, etc.

```
Stack s1 = new Stack();
Stack s2 = new Stack();

s1.push(5);
s2.push(6);
s1.push(7);

int i = s1.pop();  // 7
int j = s1.pop();  // 5
int k = s2.pop();  // 6
```

Classes

- Most object-oriented languages use classes to implement ADT's.

```
class Stack {
    private int [] data = new int[1000];
    private int top = 0;

    public void push(int n)
    { data[top++] = n; }

    public int pop()
    { return data[--top]; }
}
```

Preventing the Y2K problem ?

```
interface Date
{
  // Methods for comparing dates
  public boolean before(Date d);
  public boolean after(Date d);
  public boolean equals(Date d);

  // Formatting and parsing
  public String toString();
  public void parse(String s);

  // Month, day, year manipulation
  public int getMonth();
  public void setMonth(int mon);

  public int getDay();
  public void setDay(int day);

  public int getYear();
  public void setYear(int year);
}
```

Y2K Problem (2)

```
// Check if expiration date
// has passed

Date today;
Textfield month, year;
Boolean expired;

// Code to initialize variables, set up GUI, etc…
// ...

int mon = today.getMonth();
int yr = today.getYear();

int mon2 = Integer.parse(month.getText()).intValue();
int yr2 = Integer.parse(year.getText()).intValue();

if (yr2 + 1900 == yr)
   expired = (mon2 > mon);
else
   expired = (yr > yr2 + 1900);
```

Y2K Problem (3)

```
interface Date
{
  // Precision constants
  public final int YEAR = 0;
  public final int MONTH = 1;
  public final int DAY = 2;

  // Methods for comparing dates
  public boolean before(Date d);
  public boolean after(Date d);
  public boolean equals(Date d);

  public boolean before(Date d, int precision);
  public boolean after(Date d, int precision);
  public boolean equals(Date d, int precision);

  // Formatting and parsing
  public String toString();
  public void parse(String s);
}
```

Y2K Problem (4)

```
// Check if expiration date
// has passed

Date today, expiration;
Textfield month, year;
Boolean expired;

// Code to initialize variables, set up GUI, etc…
// ...

String expDate = month.getText() + "/" + year.getText();

expiration.parse(expDate);
expired = today.after(expiration, Date.MONTH);
```

Object-Oriented Paradigm

- Inheritance
  - Reuse mechanism by which a new class is derived from an existing class
- Overriding
  - The redefinition of an inherited method in a subclass
- Polymorphism
  - The ability of a variable to refer to objects of more than one type
- Late-binding
  - The selection of the method to invoke based on the dynamic (runtime) type of the object receiving the message

Example: Taxonomy of Animals

```
class Animal
{
  private float weight;

  boolean canFly()
  { return false; }
}

class Mammal extends Animal
{
  private Color hairColor;
}

class Bear extends Mammal
{
}
```

```
class Bird extends Animal
{
  boolean canFly()
  { return true; }
}

class Penguin extends Bird {
  boolean canFly()
  { return false; }
}

Animal a;
boolean b;
a = new Bird();
b = a.canFly(); // true
```

inheritance

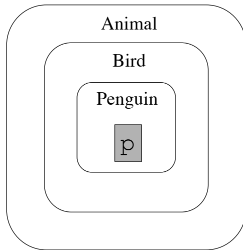
overriding

polymorphism

late binding

Class hierarchies

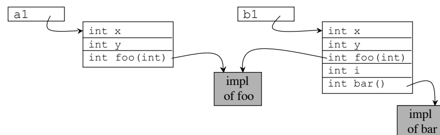
```
Penguin p = new Penguin();
```



Implementation of OO Language

```
class A {
  private int x;
  private int y;
  public int foo(int n)
  { return n*(x+y); }
}
A a1 = new A();
A a2 = b1; // OK
```

```
class B extends A {
  private int i;
  public int bar() {
    return i*(x+y); // error
    return foo(i);  // OK
  }
}
B b1 = new B();
B b2 = a1; // error
```



Example: CAD Drawing module

```
struct Circle {
  Point center;
  int radius;
};
struct Rect {
  Point topLeft;
  Point bottomRight;
};
enum { CIRCLE, RECT, … };
struct Shape {
  int type;
  union {
    Circle c;
    Rect r;
    //…
  } shape;
};
```

```
void drawCircle(struct Circle)
{
  // …
}

void redraw(struct Shape s[],
            int n)
{
  for (int i = 0; i < n; i++)
  switch(s[i].type) {
  case CIRCLE:
    drawCircle(s[i].shape.c);
    break;
  case RECT:
    drawRect(s[i].shape.r);
    break;
  // …
}
```

CAD Drawing module (OO)

```
class Shape {
  public void draw() { }
}
class Circle extends Shape {
  Point center;
  int radius;
  public void draw() {
    // …
  }
}
class Rect extends Shape {
  Point topLeft;
  Point bottomRight;
  public void draw() {
    // …
  }
}
```

```
void redraw(Shape[] s, int n)
{
  for (int i = 0; i < n; i++)
    s[i].draw();
}
```

Key Points

- Object-oriented programming style may be viewed as: message passing, simulation, metaphor, or delegation.
- Data abstraction is central to OOP
  - Defining and using abstract data types
- Inheritance, Polymorphism, and Late-binding promote the development of robust, reusable code.