OOP and Inheritance

Programming Languages

CS 214

Introduction

Let's play the children's game: *Twenty Questions*

→ You have 20 questions to guess what I'm thinking about...

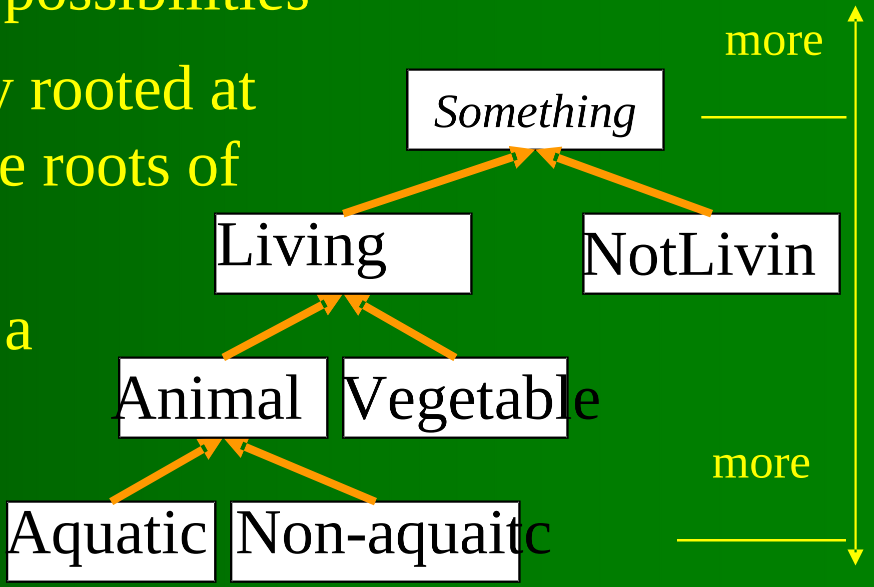
What are you trying to do with your questions?

→ *Good* questions *eliminate large classes of objects* to narrow the number of remaining possibilities

→ The game presupposes a hierarchy rooted at *Something*, whose subclasses are the roots of less general class hierarchies:

→ A good question lets you descend a *level* in the hierarchy...

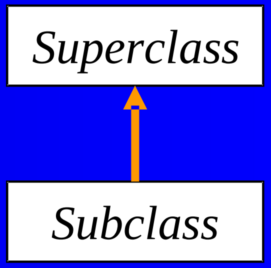
We seem to pick this hierarchy up quite early (as children)...



Object-Oriented Programming (OOP)

One of the basic aims of the *class* is to allow programmers to model objects (abstract or concrete) from the real world.

→ OOP supports *hierarchical class relationships*:



→ Each ↑ represents the *is-a* relationship, indicating that the *subclass inherits* the attributes of its *superclass*.

→ *Object-oriented analysis & design* (OOD) uses superclasses and inheritance to consolidate attributes that have different objects in *common*, so that those attributes need not be defined more than once.

Different OO languages have different conventions for representing inheritance, but the concept is the same.

Example: A Payroll Problem

Suppose we have these kinds of workers on our payroll:

- Faculty member
  - name
  - id number
  - dept
  - salary
  - research specialty
- Administrator
  - name
  - id number
  - dept
  - salary
- Staff member
  - name
  - id number
  - dept
  - hourly rate
  - hours worked
  - supervisor
- Student worker
  - name
  - id number
  - dept
  - hourly rate
  - hours worked

How can we organize these so as to avoid redundant code?

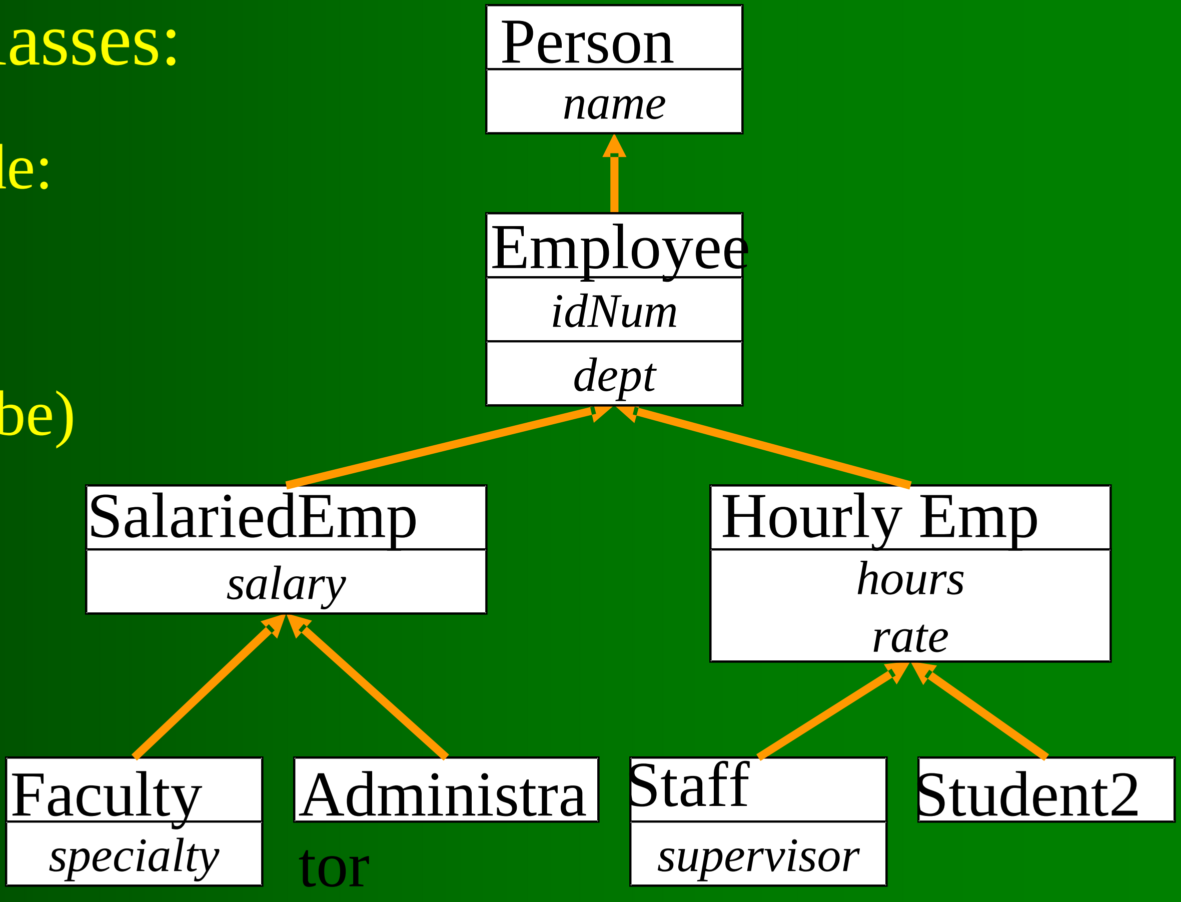
Design

We can start with the 'leaf' classes and consolidate common attributes into superclasses:

Each class should provide:

- *Constructors*
- *Accessor* methods
- *Mutator* methods (maybe)
- *I/O* methods
- *pay* method (*Employee* and below)

Note that our design process is *bottom-up*, not top-down...



Implementation: C++

Given a design, our implementation proceeds *top-down*:

```
class Person {
 public:
   Person();
   Person(string name);
   string getName() const;
   virtual void write(ostream& out) const;
   virtual void read(istream& in);
   friend ostream& operator<<(ostream & out, const Person & p);
   friend istream& operator>>(istream & in, Person & p);

 private:
   string myName;
};
```

In order for subclasses to override read() and write() with their own definitions, these must be declared as *virtual* methods in C++.

Implementation: C++ (ii)

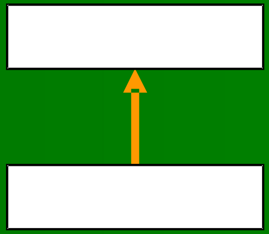
```
inline Person::Person() { myName = ""; }

inline Person::Person(string name) { myName = name; }

inline string Person::getName() const { return myName; }

inline void Person::write(ostream& out) const
 { out << myName << endl; }

inline void Person::read(istream& in) { getline(in, myName); }

inline ostream& operator<<(ostream & out, const Person& p)
  { p.write(out); return out; }

inline istream& operator>>(istream& in, Person& p)
  { p.read(in); return in; }
```

Each of these is simple enough to define *inline* in C++
(i.e., in the header file)...

Implementation: C++ (iii)

We continue with the *Employee* subclass of *Person*:

```
class Employee : public Person {
 public:
   Employee();
   Employee(string name, int id, string dept);
   int getID() const;
   string getDept() const;
   virtual void write(ostream& out) const;
   virtual void read(istream& in);
   virtual double pay() const = 0;
 private:
   int    myID;
   string myDept;
};
```



pay() is a *pure virtual* function because every *Employee* should respond to that message, but its subclasses must supply its definition.

Implementation: C++ (iv)

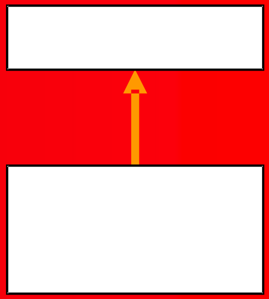
```
inline Employee::Employee()
 : Person()
{ myID = 0; myDept = ""; }

inline Employee::Employee(string name, int id, string dept)
 : Person(name)
{ myID = id; myDept = dept; assert(id > 0); }

inline int Employee::getID() const { return myID; }

inline string Employee::getDept() const { return myDept; }

inline void Employee::write(ostream& out) const {
  Person::write(out);
  out << myID << endl << myDept << endl;
}

inline void Employee::read(istream& in) {
  Person::read(in);
  in >> myID >> myDept; assert(myID > 0);
}
```

Employee inherits << and >>, and since they call *write()* and *read()*, we need not redefine them...

Implementation: C++ (v)

We continue with *Employee*’s *SalariedEmployee* subclass:

```
class SalariedEmployee : public Employee {
 public:
   SalariedEmployee();
   SalariedEmployee(string name, int id,
                    string dept, double salary);
   double getSalary() const;
   virtual void write(ostream& out) const;
   virtual void read(istream& in);
   virtual double pay() const;

 private:
  double    mySalary;
};
```



A *SalariedEmployee* has the information needed to compute its pay, so it supplies the definition for pay().

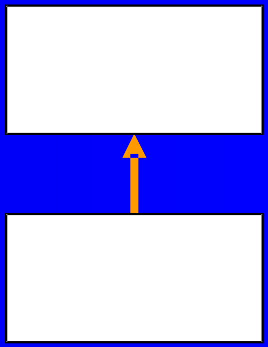
Implementation: C++ (vi)

```
inline SalariedEmployee::SalariedEmployee()
 : Employee()
{ mySalary = 0.0; }

inline SalariedEmployee::SalariedEmployee(string name, int id,
                                   string dept, double salary)
 : Employee(name, id, dept)
{ mySalary = salary; assert(mySalary > 0.0); }

inline double SalariedEmployee::getSalary() const
{ return mySalary; }

inline void SalariedEmployee::write(ostream& out) const
{ Employee::write(out);
  out << mySalary << endl; }

inline void SalariedEmployee::read(istream& in)
{ Employee::read(in);
  in >> mySalary; assert(mySalary > 0.0); }

inline double SalariedEmployee::pay() const
{ return mySalary;}
```

Implementation: C++ (vii)

We continue with the *FacultyMember* subclass:

```
class FacultyMember : public SalariedEmployee {
 public:
   FacultyMember();
   FacultyMember(string name, int id, string dept,
                 double salary, string specialty);
   string getSpecialty() const;
   virtual void write(ostream& out) const;
   virtual void read(istream& in);

 private:
  string    mySpecialty;
};
```



A *FacultyMember* inherits the *name*-, *id*-, *department*-, and *salary*-related attributes/methods from its superclass.

Implementation: C++ (viii)

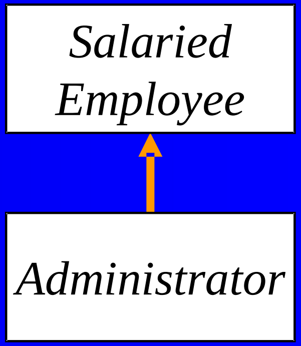
```
inline FacultyMember::FacultyMember()
 : SalariedEmployee()
{ mySpecialty = ""; }

inline FacultyMember::FacultyMember(string name, int id,
                                    string dept, double salary,
                                    string specialty)
 : SalariedEmployee(name, id, dept, salary)
{ mySpecialty = specialty; }

inline string FacultyMember::getSpecialty() const
{ return mySpecialty; }

inline void FacultyMember::write(ostream& out) const
{ SalariedEmployee::write(out);
  out << mySpecialty << endl; }

inline void FacultyMember::read(istream& in)
{ SalariedEmployee::read(in);
  in >> mySpecialty; }
```

We then do the same for the other classes in our design.

Implementation: C++ (ix)

The *Administrator* class is especially easy:

```
class Administrator : public SalariedEmployee {
 public:

   Administrator();
   Administrator(string name, int id, string dept,
                      double salary);

};

inline Administrator::Administrator() : SalariedEmployee()
{}

inline Administrator::Administrator(string name, int id,
                                    string dept, double salary)
   : SalariedEmployee(name, id, dept, salary)
{}
```



Our *Administrator* class is this simple because it has no attributes/methods beyond those it inherits from its superclass…

Use: C++

Given our hierarchy, we can write something like this:

```
// …
ifstream fin("payroll.data");
Employee* empPtr; char empType;
for (;;) {
   fin >> empType;
   if ( fin.eof() ) break;
   switch (empType) {
    case 'A': empPtr = new Administrator(); break;
    case 'F': empPtr = new FacultyMember(); break;
    case 'S': empPtr = new StaffMember(); break;
    case 'W': empPtr = new StudentWorker(); break;
   }
   fin >> (*empPtr);  // equivalent to empPtr->read(fin);
   cout << empPtr->getName() << endl
        << empPtr->pay() << endl;
}
fin.close();
// …
```

Our variable *empPtr* is called a *handle*, because it can 'grab' different objects...

Compile-Time vs Run-Time Binding

In C++, the *virtual* keyword tells the compiler to *wait until runtime* to bind messages to their definition (by default, binding occurs at compile-time in C++).

If we don't declare prototypes of *write()* as *virtual*:

```
class Employee {
 public:
   // …
   void write(ostream& out) const;
   // …
};
```

then subsequent calls to *write()*:

```
Employee* empPtr;
// …
empPtr->write(cout);
```

are statically bound to *Employee::write()* at *compile-time* (because the handle is an *Employee**) instead of being dynamically bound to the receiver's *write()* at *run-time*.

Polymorphism

By declaring *read()* and *write()* as *virtual*:

```
class Person {
  // …
  virtual void write(ostream& out) const;
  virtual void read(istream& in);
  // …
};
```

subsequent calls to these methods:

```
Employee* empPtr;
// …
empPtr->write(cout);
```

are bound to the *receiver's* definitions of those methods at *run-time*.

- The same call to *write()* may thus invoke *FacultyMember::write()*, *Administrator::write()*, *StaffMember::write()* or *StudentWorker::write()* depending on the object to which the handle *empPtr* points.
- This behavior is called *polymorphic behavior*, or *polymorphism*.
- *Dynamic dispatch* (aka *runtime binding*) is the mechanism by which a message is bound according to *the receiver's type*, instead of the handle's type.

Implementation: Java

Let’s compare our C++ implementation to Java:

```
public class Person {
  public Person() { myName = ""; }
  public Person(String name) { myName = name; }
  public final String getName() { return myName; }
  public void write(PrintWriter out) { out.println(myName); }
  public void read(BufferedReader in) { myName = in.readLine(); }

  private String myName;
}
```

Java has no operator overloading, no const methods and no friends.

In C++, compile-time binding is the default; run-time binding (polymorphism) must be enabled using the *virtual* keyword.

In Java, run-time binding (polymorphism) is the default; compile-time binding must be enabled using the *final* keyword.

Implementation: Java (ii)

Continuing with the *Employee* subclass of *Person*:

```
abstract class Employee extends Person {
  public Employee() { super(); myID = 0; myDept = ""; }

  public Employee(String name, int id, String dept)
  { super(name); myID = id; myDept = dept; }

  public final int getID() { return myID; }

  public final String getDept() { return myDept; }

  public void write(PrintWriter out)
  { super.write(out); out.println(myID); out.println(myDept); }

  public void read(BufferedReader in)
  { super.read(in); String idString = in.readLine();
    myID = Integer.parseInt(idString); myDept = in.readLine(); }

   abstract public double pay();     // "pure virtual" in Java
   private int    myID;
   private String myDept;
}
```

Implementation: Java (iii)

```
class SalariedEmployee extends Employee {
 public SalariedEmployee() { super(); mySalary = 0.0; }

 public SalariedEmployee(String name, int id,
                         String dept, double salary)
 { super(name, id, dept); mySalary = salary; }

 public final double getSalary() { return mySalary; }

 public void write(PrintWriter out)
  { super.write(out); out.println(mySalary); }

 public void read(BufferedReader in)
  { super.read(in); String salaryString = in.readLine();
    mySalary = Double.parseDouble(salaryString); }
 public double pay() { return mySalary; }
 private double mySalary;
}
```

Java lets us do most of the same things, but (usually) more easily...

Implementation: Java (iv)

```
class FacultyMember extends SalariedEmployee {
 public FacultyMember() { super(); mySpecialty = ""; }

 public FacultyMember(String name, int id, String dept,
               double salary, String specialty)
  { super(name, id, dept, salary); mySpeciality = specialty; }

 public final String getSpecialty() { return mySpecialty; }

 public void write(PrintWriter out)
  { super.write(out); out.println(mySpecialty); }

 public void read(BufferedReader in)
  { super.read(in); mySpecialty = in.readLine(); }

 private String mySpecialty;
}
```

We then implement the other classes the same way...

Implementation: Java (v)

As before, *Administrator* indicates how easy this is:

```
class Administrator extends SalariedEmployee {
  public Administrator() { super(); }

  public Administrator(String name, int id, String dept,
                       double salary)
   { super(name, id, dept, salary); }
}
```

Our *Administrator* class is this simple because it has no attributes/methods beyond those it inherits from its superclass…

Use: Java

To use these classes, we can write something like this:

```
// …
BufferedReader fin = new BufferedReader(
                      new InputStreamReader(
                       new FileReader("payroll.data")));
Employee emp = null; String eType = null;
for (;;) {
  eType = fin.readLine();         // name of class
  if ( eType == null ) break;
  Employee emp = (Employee) Class.forName(eType).newInstance();
  emp.read(fin);
  System.out.println( emp.getName() + "\n" + emp.pay() );
}
fin.close();
// …
```

All non-primitive-type variables are handles (pointers) in Java.

Java's *Class* class provides a very convenient way to build an instance of a class from a string whose value is the name of the class.

Implementation: Ada

Let's compare Ada to our other implementations:

```
package PersonPackage is
   type Person is tagged private;
   type PersonRef is access all Person'Class;
   procedure Init(P: in out Person; AName: Unbounded_String);
   function GetName(P: in Person) return Unbounded_String;
   procedure Read(F: in out File_Type; P: in out Person);
   procedure Write(F: in out File_Type; P: in Person);
   procedure Put(F: in out File_Type; P: in Person'Class);
   procedure Get(F: in out File_Type; P: in out Person'Class);
private
   type Person is tagged record
        itsName : Unbounded_String;
    end record;
end PersonPackage;
```

In Ada, a *subtype* can inherit from a *tagged* type (for polymorphism);

and a *handle* is declared as a pointer to a *Class-wide* type.

Implementation: Ada (ii)

Our package body is as follows:

```
package body PersonPackage is
 procedure Init(P: in out Person; AName: Unbounded_String) is
  begin
    P.ItsName := AName;
 end Init;
 function GetName(P: in Person) return Unbounded_String is
  begin
    return P.ItsName;
 end GetName;
 procedure Write(F: in out File_Type; P: in Person) is begin
    Put(F, P.ItsName); New_Line(F);
 end Write;
 procedure Put(F: in out File_Type; P: in Person'Class) is
  begin
       Write(F, P);   -- P is class-wide -> dynamic dispatch
 end Put;
 -- … Read, Get are similar …
end PersonPackage;
```

Implementation: Ada (iii)

We then build *Employee* as an extension of *Person*:

```
package EmployeePackage is
 type Employee is abstract new Person with private;
 type EmployeeRef is access all Employee'Class;
 procedure Init(E: in out Employee; name: Unbounded_String;
                id: Integer; dept: Unbounded_String);
 function GetID(E: in Employee) return Integer;
 function GetDept(E: in Employee) return Unbounded_String;
 procedure Write(F: in out File_Type; E: in Employee);
 procedure Read(F: in out File_Type; E: in out Employee);
 function GetPay(E: in Employee'Class) return float;
 function Pay(E: in Employee) return float is abstract;

private
  type Employee is abstract new Person with record
      itsID : Integer;
      itsDept : Unbounded_String;
   end record;
end EmployeePackage;
```

Implementation: Ada (iv)

```
package body EmployeePackage is
 procedure Init(E: in out Employee; Name: in Unbounded_String;
                Id: in Integer; Dept: in Unbounded_String)
  is begin
    Init(Person(E), Name); E.ItsID := Id; E.ItsDept := Dept;
 end Init;
 function GetId(E: in Employee) return Integer is begin
    return Emp.ItsId;
 end GetId;
 -- … GetDept() is similar …
 procedure Write(F: in out File_Type; E: in Employee) is begin
    Write(F, Person(E));
    Put(F, E.ItsId); New_line(F);
    Put(F, E.ItsDept); New_Line(F);
 end Write;
 -- … read(F, E) is similar; Get(F,E), Put(F,E) are not needed!
 function GetPay(E: in Employee'Class) return float is begin
    return Pay(E);    // E is class-wide -> dynamic dispatch
 end GetPay;
end EmployeePackage;
```

Implementation: Ada (v)

We then build *SalariedEmployee* as an extension of *Employee*:

```
package SalariedEmployeePackage is
 type SalariedEmployee is new Employee with private;
 type SalariedEmployeeRef is access all SalariedEmployee'Class;

 procedure Init(sE: in out SalariedEmployee;
               Name: in Unbounded_String; Id: in Integer;
               Dept: in Unbounded_String; Salary: in Float);

 function GetSalary(sE: in SalariedEmployee) return Float;

 procedure Write(F: in out File_Type; sE: in SalariedEmployee);

 procedure Read(F: in out File_Type;
               sE: in out SalariedEmployee);

 function Pay(sE: in SalariedEmployee) return Float;

private
  type SalariedEmployee is new Employee with record
      itsSalary : Float;
   end record;
end SalariedEmployeePackage;
```

Implementation: Ada (vi)

```
package body SalariedEmployeePackage is
 procedure Init(sE: in out SalariedEmployee;
                     Name: in Unbounded_String; Id: in Integer;
                     Dept: in Unbounded_String; Salary: in Float)
  is begin
    Init(Employee(sE), Name, Id, Dept); sE.ItsSalary := Salary;
 end Init;
 function GetSalary(sE: in SalariedEmployee) return Float is
  begin
    return sE.ItsSalary;
 end GetSalary;
 procedure Write(F: in out File_Type; sE: out SalariedEmployee)
  is begin
    Write(F, Employee(sE));
    Put(F, sE.ItsSalary); New_line(F);
 end Write;
 -- … Read(F, sE) is similar…
 function Pay(sE: in SalariedEmployee) return Float is begin
    return mySalary;
 end Pay;
end SalariedEmployeePackage ;
```

Implementation: Ada (vii)

We then build *Faculty* as an extension of *SalariedEmployee*:

```
package FacultyPackage is
 type Faculty is new SalariedEmployee with private;
 type FacultyRef is access all Faculty'Class;

 procedure Init(F: in out Faculty; Name: in Unbounded_String;
             Id: in Integer; Dept: in Unbounded_String;
             Salary: in Float; Specialty: in Unbounded_String);

 function GetSpecialty(F: in Faculty) return Unbounded_String;

 procedure Write(outf: in out File_Type; F: in Faculty);

 procedure Read(inF: in out File_Type; F: in out Faculty);


private
  type Faculty is new SalariedEmployee with record
      itsSpecialty : Unbounded_String;
   end record;
end FacultyPackage;
```

Implementation: Ada (viii)

```
package body FacultyPackage is
 procedure Init(F: in out Faculty; Name: in Unbounded_String;
                Id: in Integer; Dept: in Unbounded_String;
                Salary: in Float; Specialty: in Unbounded_String)
  is begin
    Init(SalariedEmployee(F), Name, Id, Dept, Salary);
    F.ItsSpecialty := Specialty;
 end Init;

 function GetSpecialty(F: in Faculty) return Unbounded_String
  is begin
    return F.ItsSpecialty;
  end GetSpecialty;

 procedure Write(outf: in out File_Type; F: in Faculty) is
  begin
    Write(outf, SalariedEmployee(F));
    Put(outf, F.ItsSpecialty); New_Line(F);
  end Write;

  -- … Read(outf, F) is similar…
end FacultyPackage ;
```

Implementation: Ada (ix)

We then build *Administrator* as an extension of *SalariedEmployee*:

```
package AdministratorPackage is
 type Administrator is new SalariedEmployee with private;
 type AdministratorRef is access all Administrator'Class;

private
  type Administrator is new SalariedEmployee with record
      null;
   end record;
end AdministratorPackage;
```

Class *Administrator* inherits everything it needs from its superclass *SalariedEmployee*, so its package body is empty:

```
package body AdministratorPackage is
  -- empty body; Administrator defines no new attributes
end AdministratorPackage ;
```

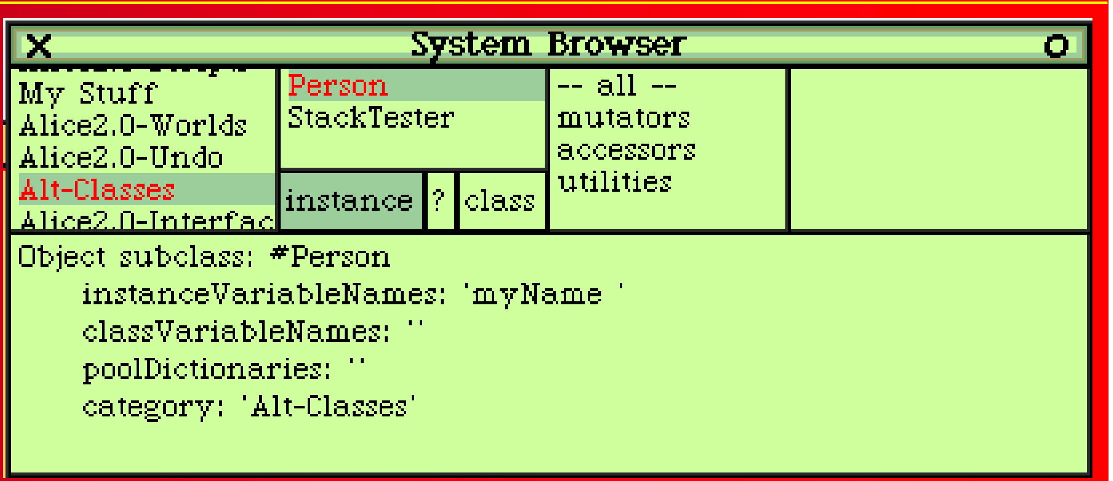
Use: Ada

```
Procedure payroll is
  EmpRef : EmployeeRef; fin: File_Type;
  eType: Character; Discard: Unbounded_String;
begin
  Open(fin, In_File, "payroll.dat");
  loop
    Get(fin, eType);  Discard := Get_Line(fin); // 'F', 'A', …
    exit when End_Of_File(fin);
    if empType = 'F' then EmpRef := new Faculty;
    elsif empType = 'A' then EmpRef := new Administrator;
    elsif empType = 'S' then EmpRef := new StaffMember;
    elsif empType = 'W' then EmpRef := new StudentWorker;
    end if;
    Get(EmpRef.all, fin);
    Put( GetName(EmpRef.all) ); New_Line;
    Put( GetPay(EmpRef.all) ); New_Line;
  end loop;
  close(fin);
// …
```

OO capabilities are an add-on in Ada, and they feel like it...

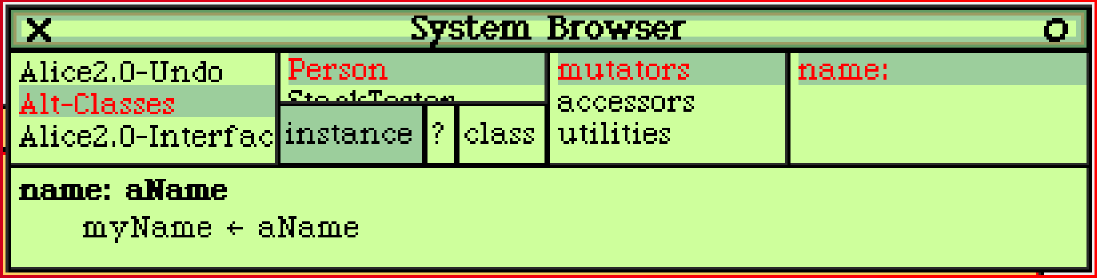
Implementation: Smalltalk

Smalltalk’s GUI makes it easy to build our *Person* class:



```
Object subclass: #Person
      instanceVariableNames: 'myName '
      classVariableNames: ''
      poolDictionaries: ''
      category: 'Alt-Classes'
```

We provide an *initialization* instance method:



```
name: aName
      myName ← aName
```

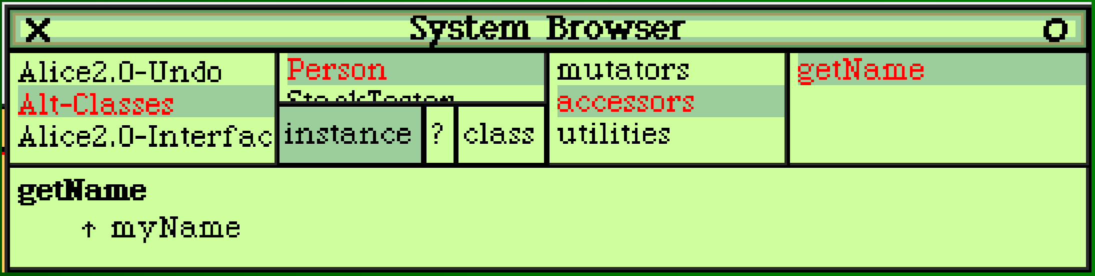
Person inherits the *new* (class method) constructor from *Object*:

This allows us to write: `p := Person new name: 'Ann'.`

to *construct* and *initialize* a *Person*.

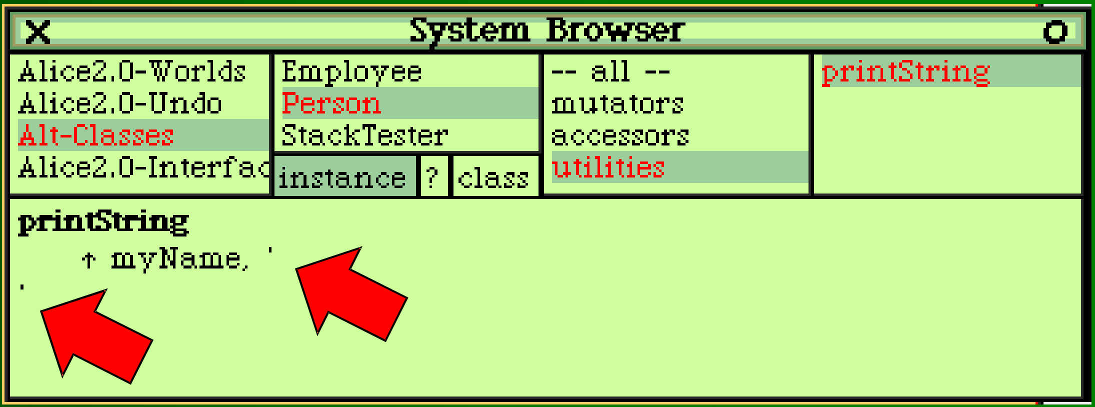
Implementation: Smalltalk (ii)

The *name accessor* is easy:



```
getName
     ↑ myName
```

And to facilitate output, we define *printString* for a *Person*:

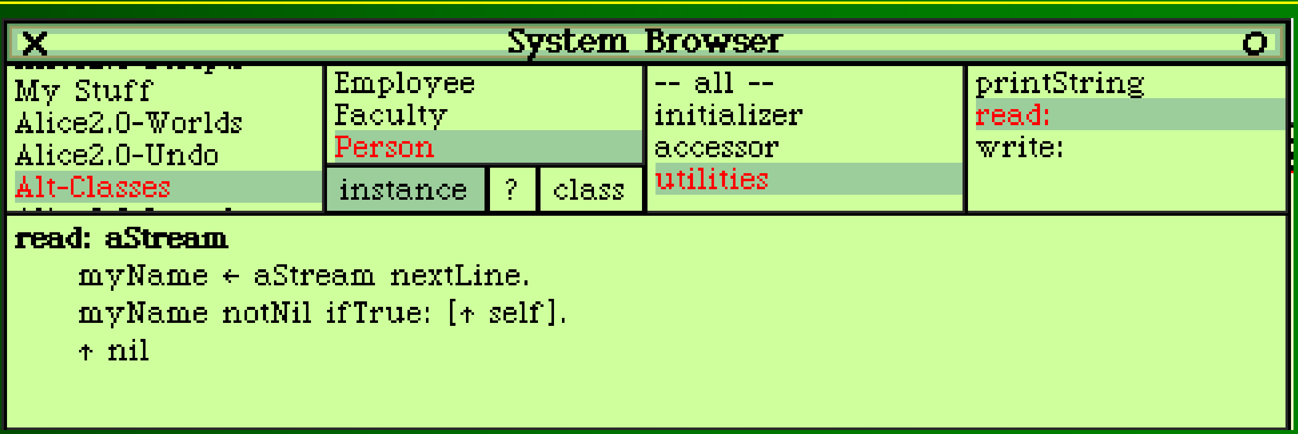


```
printString
     ↑ myName, '
'
```

Note that Smalltalk allows strings to contain *embedded newlines*, which we use to separate *myName* from what follows it...

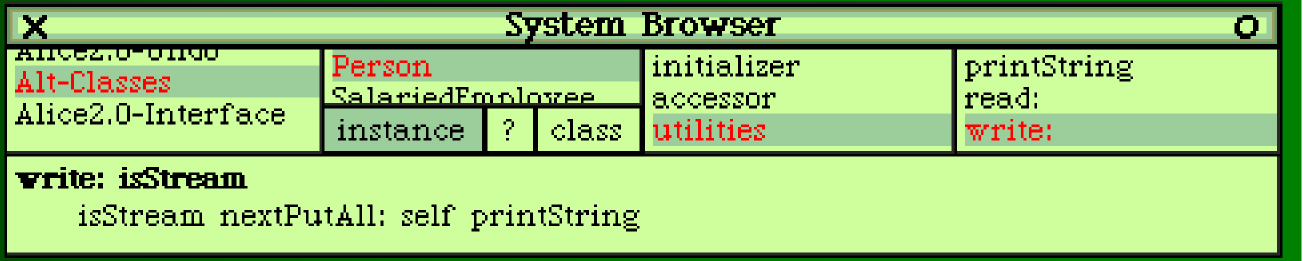
Implementation: Smalltalk (iii)

We might define a *read:* method as follows:



```
read: aStream
    myName ← aStream nextLine.
    myName notNil ifTrue: [↑ self].
    ↑ nil
```

plus a *write:* method that uses *printString* to display itself:



```
write: isStream
    isStream nextPutAll: self printString
```

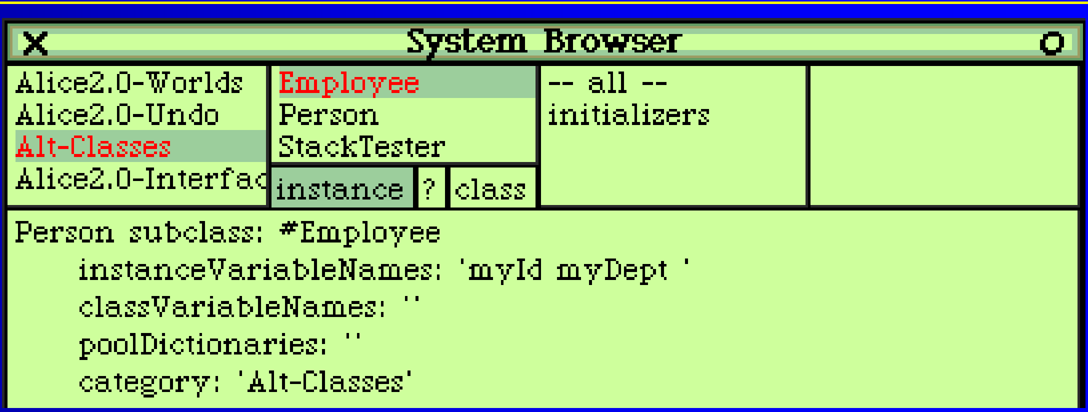
This lets us write:

```
p := Person new name: 'Ann'.
f := FileStream newFileNamed: 'data.txt'.
p write: f.
```

to create a stream to a file and write a *Person* to it.

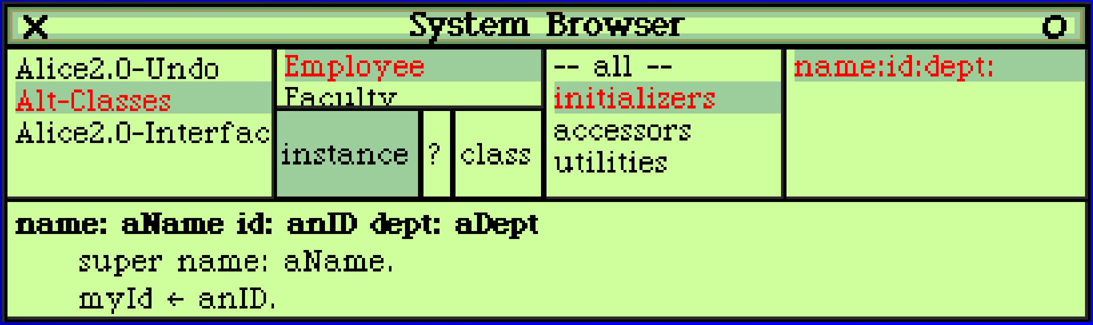
Implementation: Smalltalk (iv)

We then build our *Employee* class as a subclass of *Person*:



```
Person subclass: #Employee
    instanceVariableNames: 'myId myDept '
    classVariableNames: ''
    poolDictionaries: ''
    category: 'Alt-Classes'
```

plus a method to *initialize* an *Employee*:



```
name: aName id: anID dept: aDept
    super name: aName.
    myId ← anID.
```

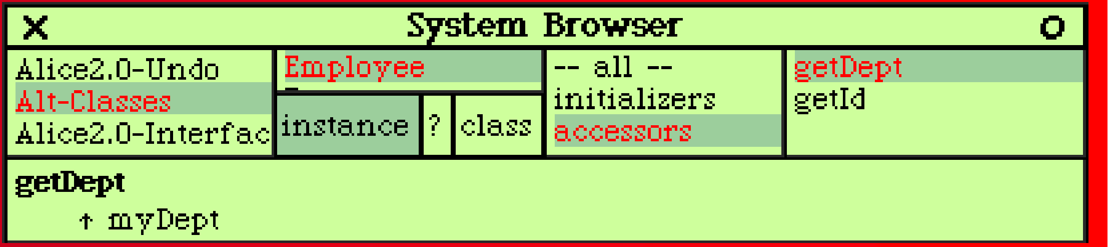
It is good practice to use superclass methods (e.g., `super name: aName`)

To manipulate superclass instance variables:

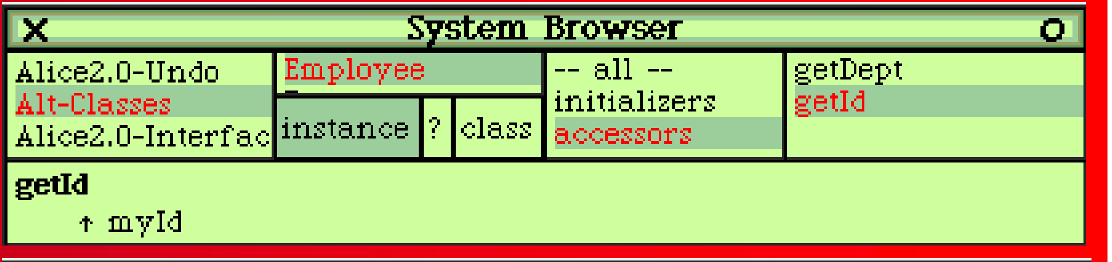
- It reuses we invested in writing those methods (avoid redundant code).
- If we alter the superclass method, the subclass auto-inherits the change.

Implementation: Smalltalk (v)

We then define *accessors* for the instance variables:

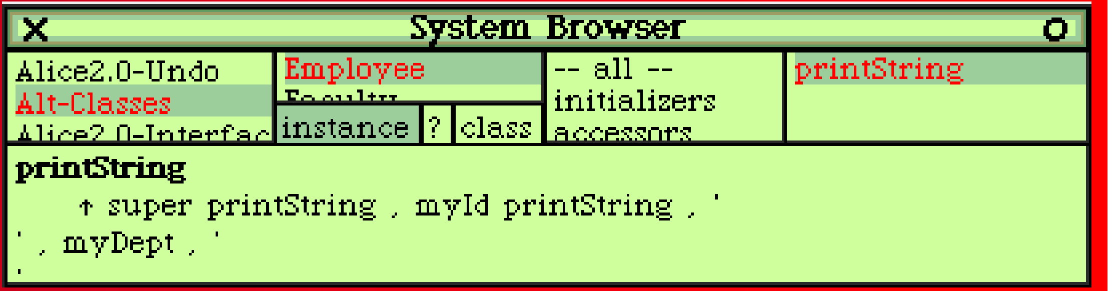


```
getDept
    ↑ myDept
```



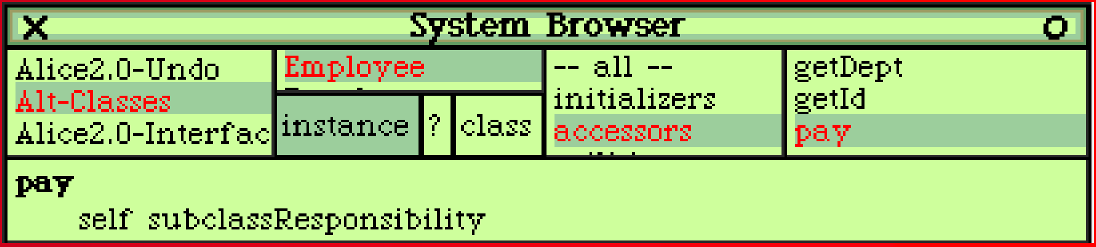
```
getId
    ↑ myId
```

printString to facilitate output (using the superclass version):



```
printString
    ↑ super printString , myId printString , '
' , myDept , '
'
```

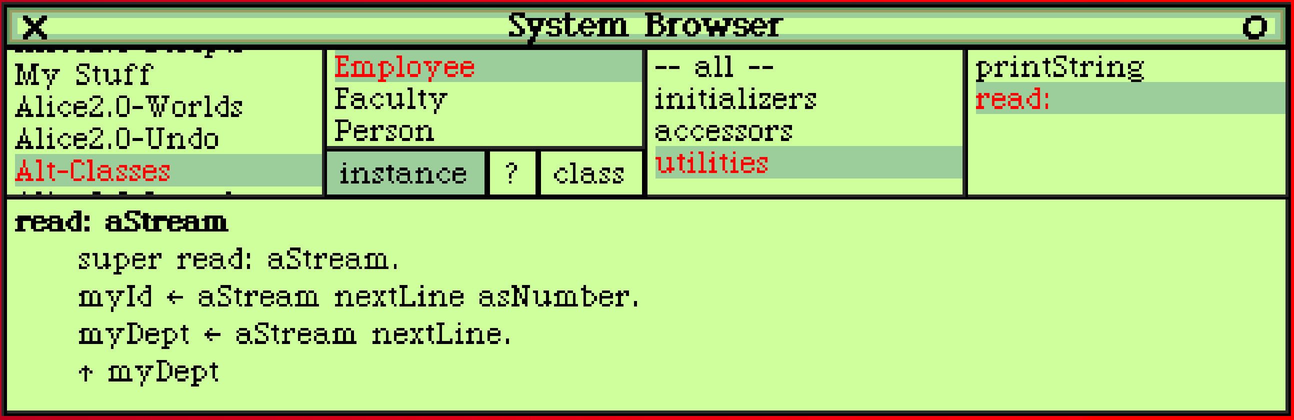
and *pay* as an abstract / "pure virtual" method:



```
pay
    self subclassResponsibility
```

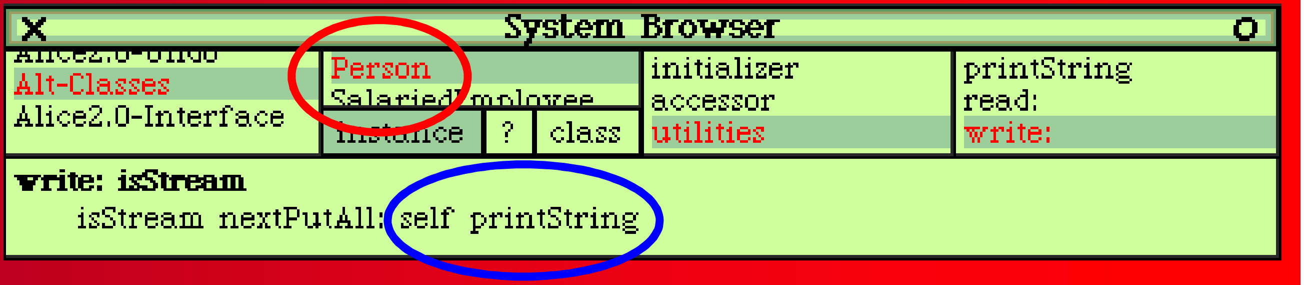
Implementation: Smalltalk (vi)

We can then override *read:* as follows:



```
read: aStream
    super read: aStream.
    myId ← aStream nextLine asNumber.
    myDept ← aStream nextLine.
    ↑ myDept
```

Because (i) the *write:* we inherit from *Person* uses *printString* to display itself,



```
write: isStream
    isStream nextPutAll: self printString
```

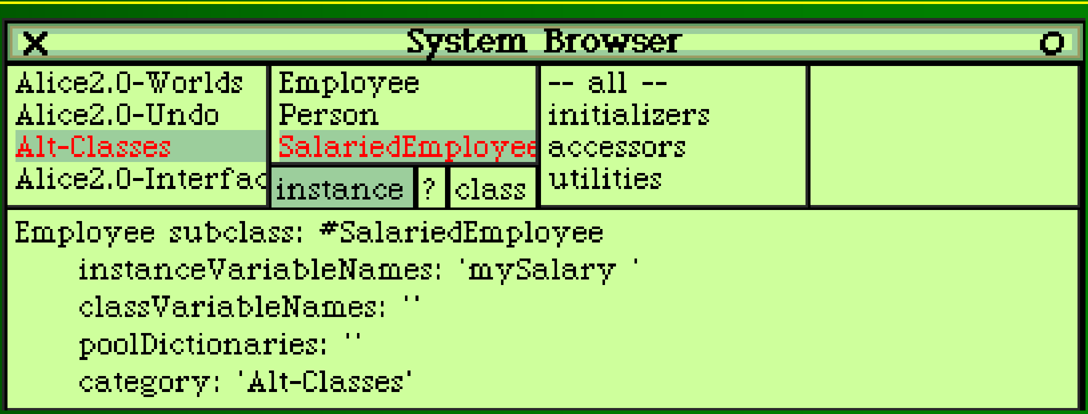
(ii) we have defined *printString* in class *Employee*, and

(iii) *All* Smalltalk methods are *polymorphic*,

the *write:* we inherit from *Person* will correctly output an *Employee*...

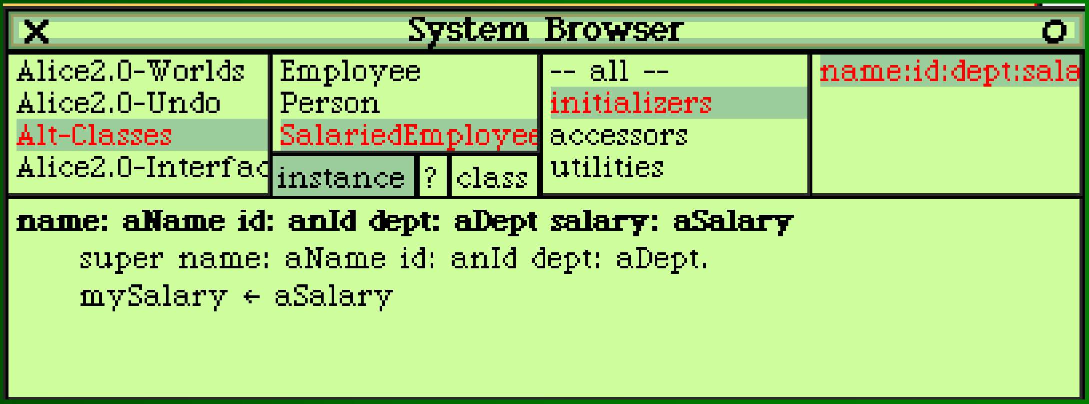
Implementation: Smalltalk (vii)

We then build our *SalariedEmployee* class as a subclass of *Employee*:



```
Employee subclass: #SalariedEmployee
    instanceVariableNames: 'mySalary '
    classVariableNames: ''
    poolDictionaries: ''
    category: 'Alt-Classes'
```

plus a method to *initialize* an *SalariedEmployee*:

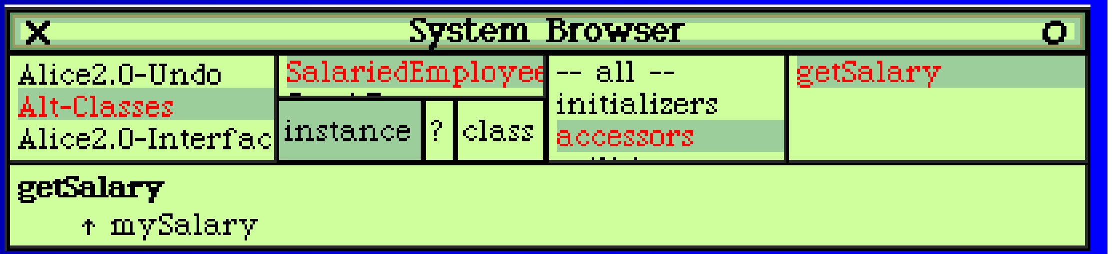


```
name: aName id: anId dept: aDept salary: aSalary
    super name: aName id: anId dept: aDept.
    mySalary ← aSalary
```

As before, we reuse the work we invested in our superclass methods and thus recoup the work we invested in writing them.

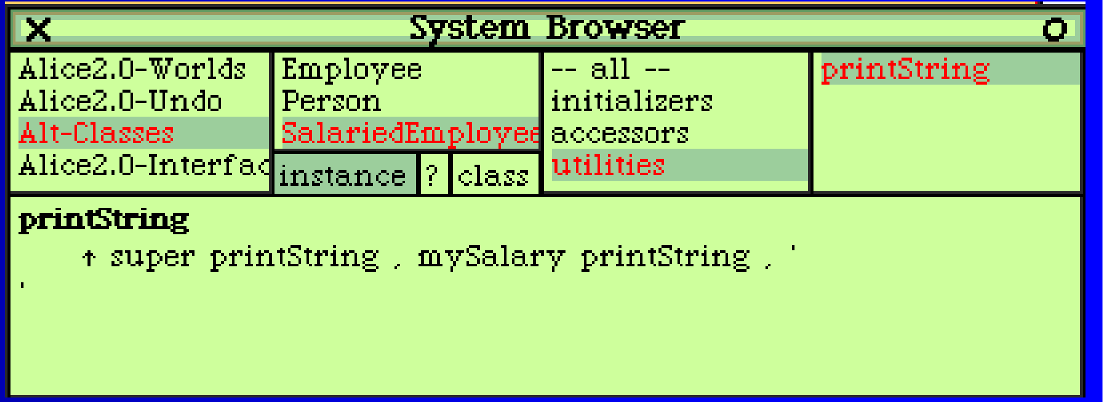
Implementation: Smalltalk (viii)

We then define an *accessor* for our instance variable:



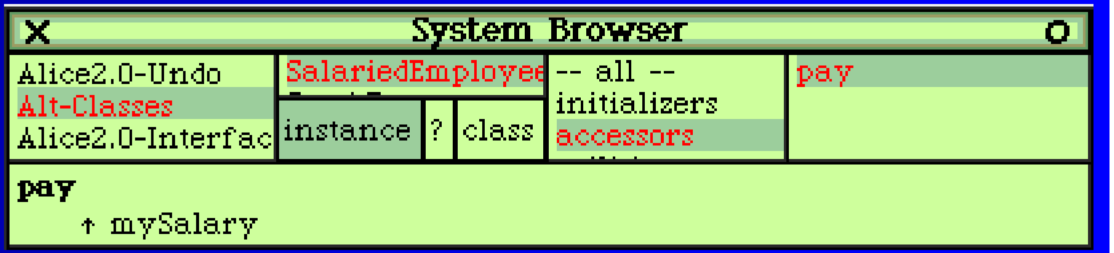
```
getSalary
    ↑ mySalary
```

printString to facilitate output:



```
printString
    ↑ super printString , mySalary printString , '
'
```

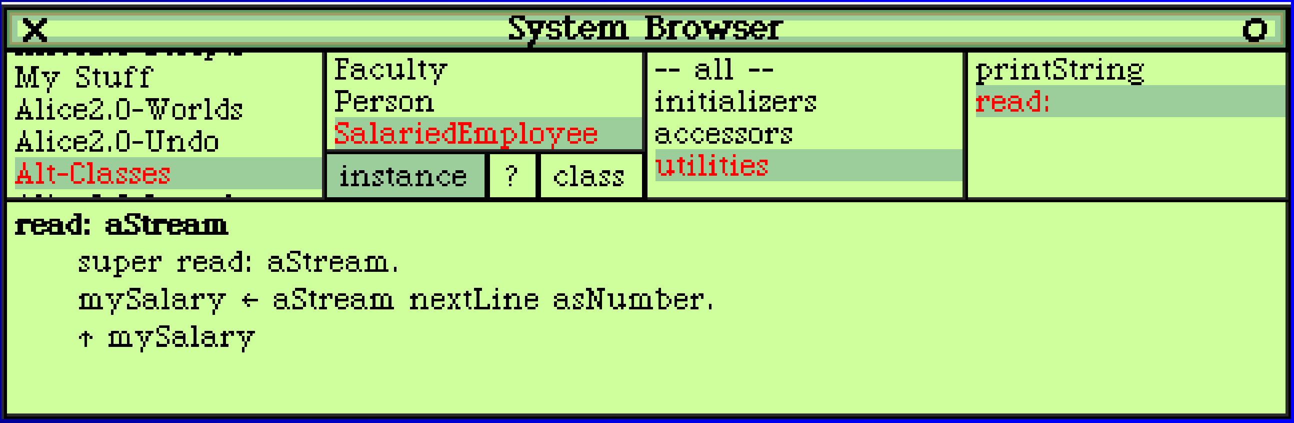
and the polymorphic *pay* method:



```
pay
    ↑ mySalary
```

Implementation: Smalltalk (ix)

We can then override *read:* as follows:



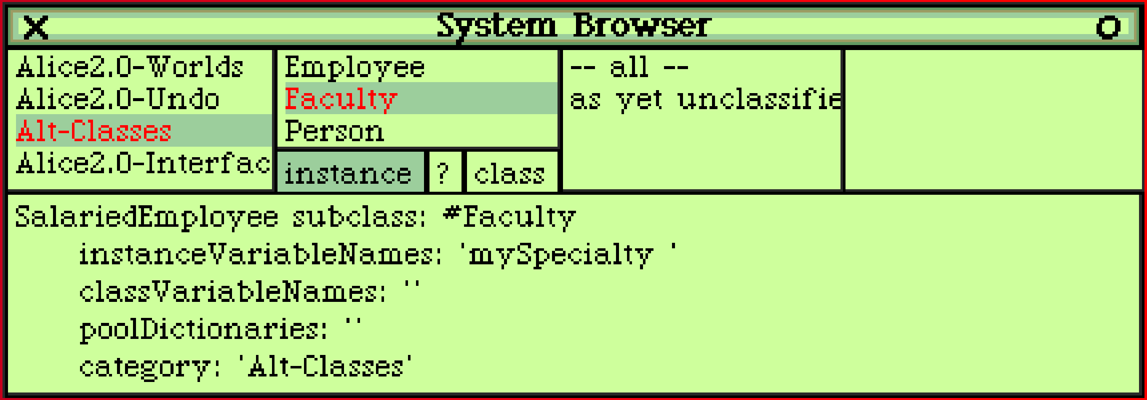
```
read: aStream
    super read: aStream.
    mySalary ← aStream nextLine asNumber.
    ↑ mySalary
```

As before, our definition of (polymorphic) *printString* means that the *write:* we inherit from *Person* will correctly output a *SalariedEmployee* without any further work on our part.

We could have performed input similarly, if we had defined *read:* in *Person* to use `self fromString` and then defined *fromString* in *Person* and each of its subclasses.

Implementation: Smalltalk (x)

We then build our *Faculty* class as a subclass of *SalariedEmployee*:

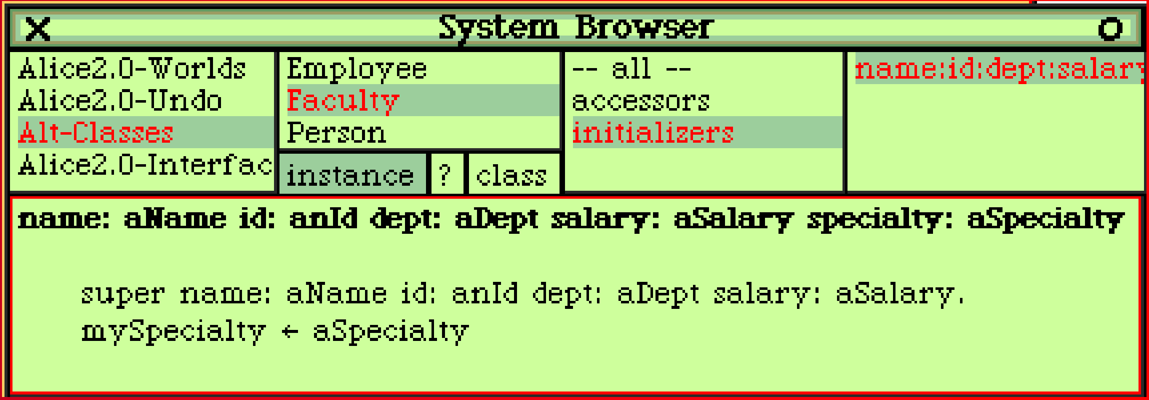


System Browser

Alice2.0-Worlds	Employee	-- all --	
Alice2.0-Undo	Faculty	as yet unclassifie	
Alt-Classes	Person		
Alice2.0-Interfac	instance ? class		

```
SalariedEmployee subclass: #Faculty
    instanceVariableNames: 'mySpecialty '
    classVariableNames: ''
    poolDictionaries: ''
    category: 'Alt-Classes'
```

plus methods to *initialize*:

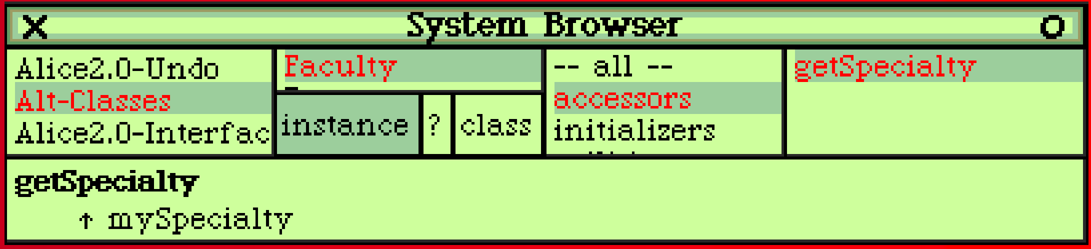


System Browser

Alice2.0-Worlds	Employee	-- all --	name:id:dept:salary
Alice2.0-Undo	Faculty	accessors	
Alt-Classes	Person	initializers	
Alice2.0-Interfac	instance ? class		

```
name: aName id: anId dept: aDept salary: aSalary specialty: aSpecialty

    super name: aName id: anId dept: aDept salary: aSalary.
    mySpecialty ← aSpecialty
```

and *access* its instance variable:



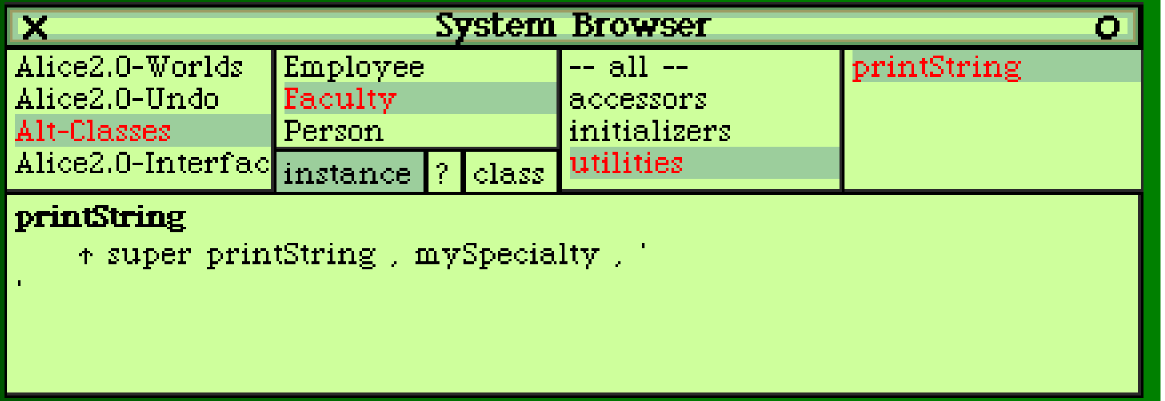
System Browser

Alice2.0-Undo	Faculty	-- all --	getSpecialty
Alt-Classes		accessors	
Alice2.0-Interfac	instance ? class	initializers	

```
getSpecialty
    ↑ mySpecialty
```

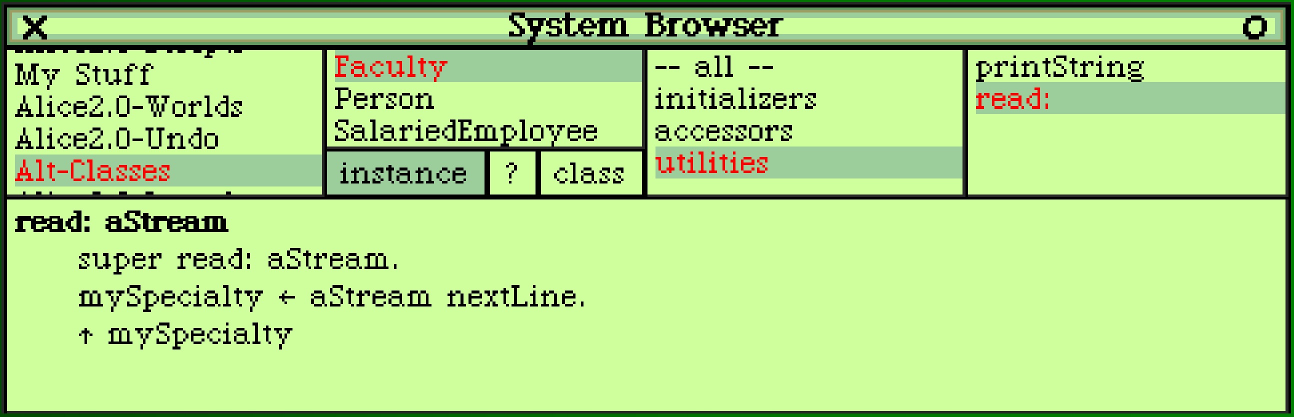
Implementation: Smalltalk (xi)

We then define *printString* to facilitate output:



```
printString
    ↑ super printString , mySpecialty , '
'
```

and override *read:* to provide input:



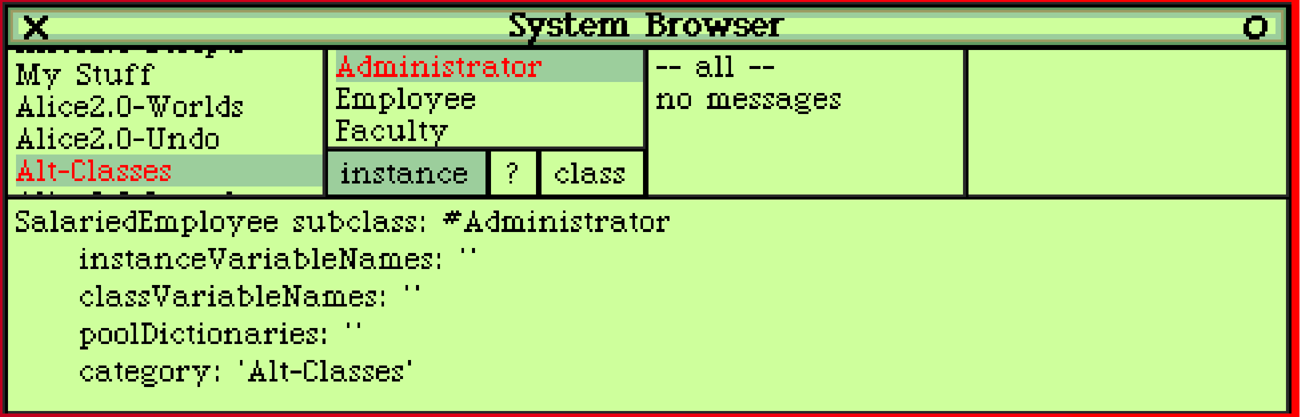
```
read: aStream
    super read: aStream.
    mySpecialty ← aStream nextLine.
    ↑ mySpecialty
```

We then build the other classes in our design in a similar fashion, using inheritance and polymorphism to avoid redundant coding...

Implementation: Smalltalk (xii)

Administrator indicates how easy this is:

The class has no attributes beyond what it inherits from its superclass:



```
SalariedEmployee subclass: #Administrator
    instanceVariableNames: ''
    classVariableNames: ''
    poolDictionaries: ''
    category: 'Alt-Classes'
```

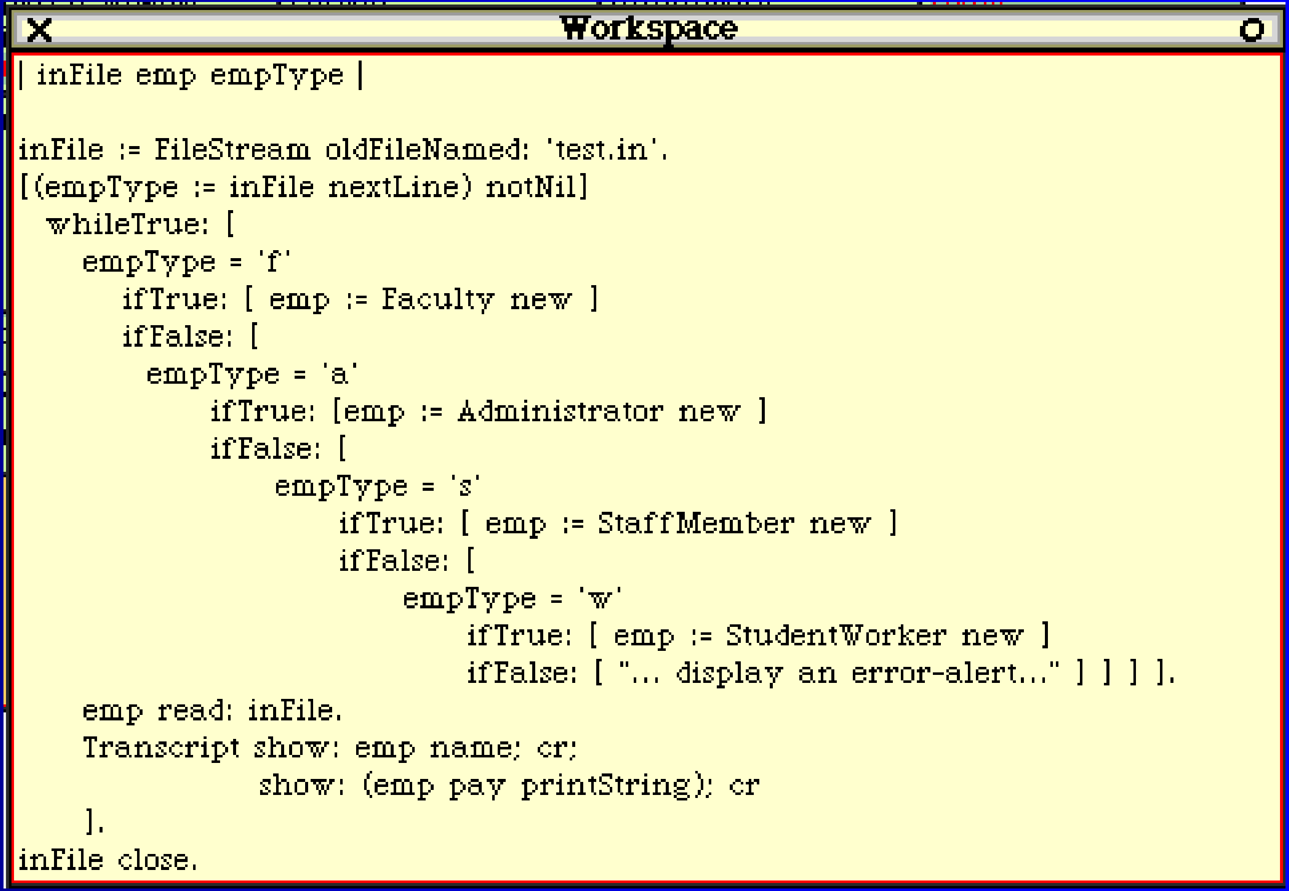
And since Smalltalk separates *construction* from *initialization*:

- Construction is via *new* inherited from *Object*;
- Initialization is via *name:id:dept:salary* inherited from *SalariedEmployee*;

we're done with *Administrator*!

Use: Smalltalk

Given the class hierarchy our design calls for, we can write something like this as the *run* method of a class that solves our payroll problem:


Workspace

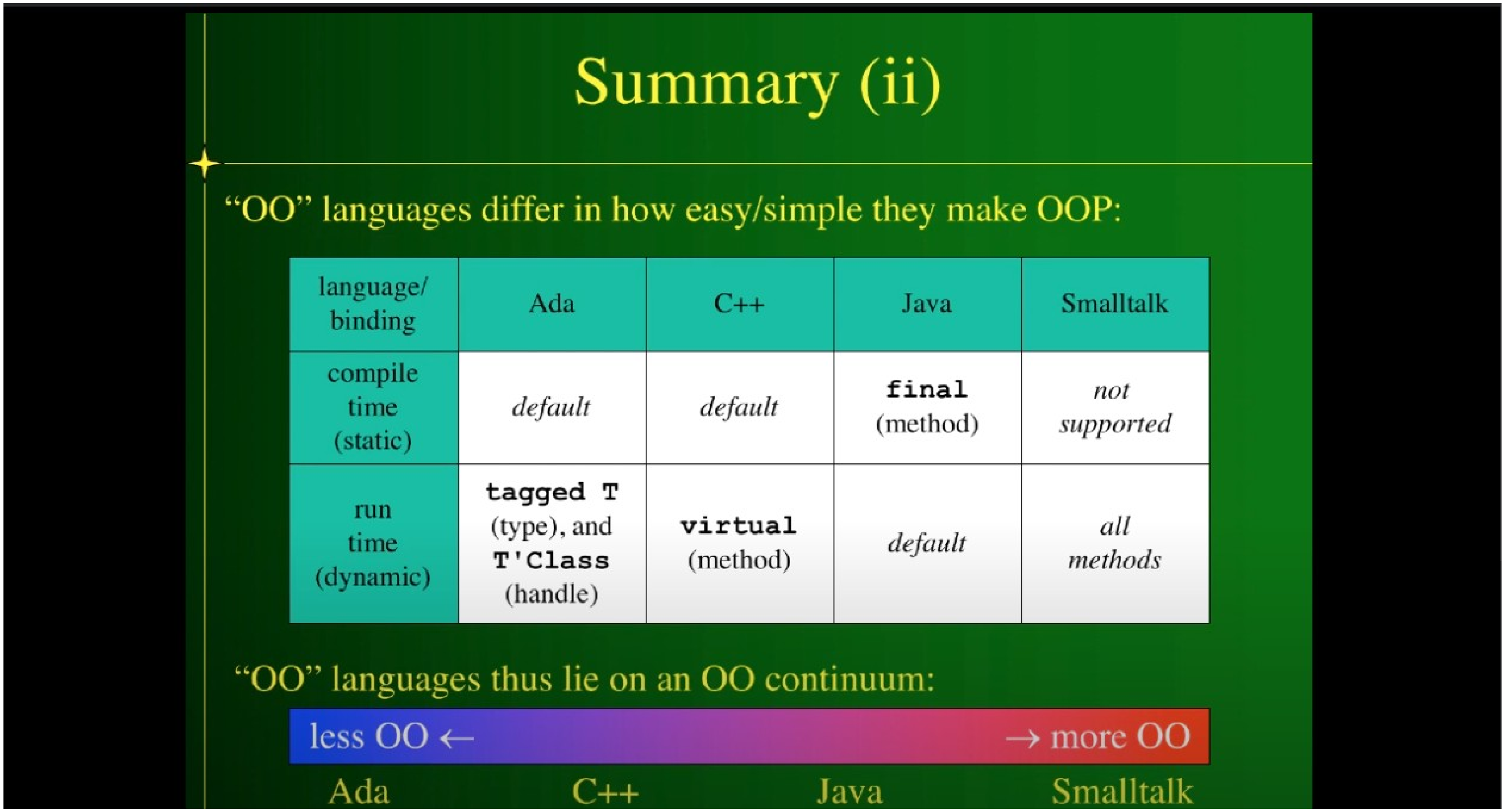
```
| inFile emp empType |

inFile := FileStream oldFileNamed: 'test.in'.
[(empType := inFile nextLine) notNil]
  whileTrue: [
    empType = 'f'
      ifTrue: [ emp := Faculty new ]
      ifFalse: [
        empType = 'a'
           ifTrue: [emp := Administrator new ]
           ifFalse: [
               empType = 's'
                  ifTrue: [ emp := StaffMember new ]
                  ifFalse: [
                      empType = 'w'
                         ifTrue: [ emp := StudentWorker new ]
                         ifFalse: [ "... display an error-alert..." ] ] ] ].
    emp read: inFile.
    Transcript show: emp name; cr;
                 show: (emp pay printString); cr
    ].
inFile close.
```

Summary

Object-oriented programming (OOP) is a way to build a system made up of a hierarchy of classes that reflects *real-world relationships*.

- A *subclass* inherits the attributes (data + operations) of its *superclass*.
- *Run-time binding (or dynamic dispatch)* ensures that when a message is sent to an object, the message is delivered to that object *first*:
  - If its class defines that message, that definition is invoked;
  - Otherwise, the message is sent "upward" in the hierarchy to the parent class, where the process is repeated.
  - If the message reaches the root class without finding a definition, a run-time error occurs.

This is called *polymorphism*, because the same message: *handle msg* may produce very different behaviors, depending on the receiver.



Summary (ii)

“OO” languages differ in how easy/simple they make OOP:

language/ binding	Ada	C++	Java	Smalltalk
compile time (static)	*default*	*default*	`final` (method)	*not supported*
run time (dynamic)	`tagged T` (type), and `T'Class` (handle)	`virtual` (method)	*default*	*all methods*

“OO” languages thus lie on an OO continuum:

less OO ← → more OO

Ada C++ Java Smalltalk