Topic 6: Procedural abstraction and data abstraction (methods and classes)

1. Modular decomposition
2. Java methods (subprograms)
3. Variables, parameters, and return values
4. Data abstraction and classes
5. Interface and implementation

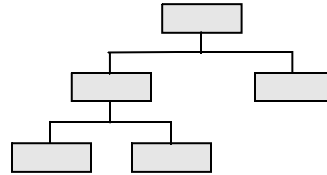
Reading: Chs. 5-6

Objectives

16. Define a Java method with parameters and a return value
17. Define a Java class

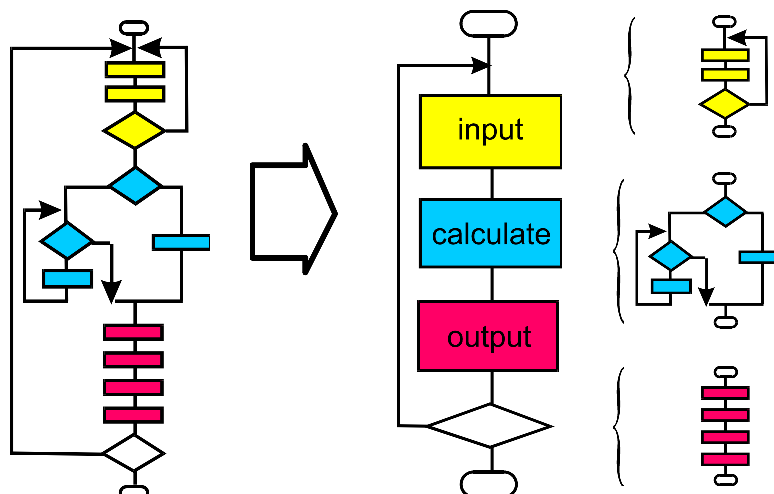
1. Modular decomposition

- Some solutions are too complex to be easily understood as a single unit
- A structured design can be decomposed into simpler *modules*



- This breaking down is called *modular decomposition*, implemented by *procedural abstraction* (writing of subprograms)
- We may continue the breakdown as needed by *stepwise refinement*

Modular decomposition: case study

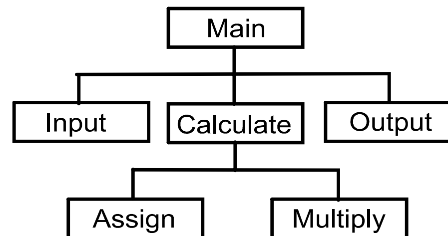


Separate modules are easier to understand.

Module hierarchy diagrams

- *Example:*
  Main invokes *Input, Calculate,* and *Output;*
  Calculate calls *Assign* and *Multiply*

Main
A. Input
B. Calculate
    1. Assign
    2. Multiply
C. Output



- A module hierarchy chart shows module dependencies, whereas a flowchart shows order of execution.

Procedural abstraction

- *Procedural abstraction* is the definition of *named subprograms* in structured design
- Statements and control structures are packaged as subprograms and the statements are replaced by calls to the subprograms
- Procedural abstraction enables modularity and reuse of code
- Defining data types, including classes, is called data abstraction, part of object-oriented design

2. Java methods (subprograms)

- In Java, subprograms are called "methods"; these are not general ways of doing things, but specific sequences of commands
- All Java methods are members of *classes*
- Every program defines at least one class with a special method, *main,* that executes when the program executes
- Other methods may be defined and may be called from *main*

Private method example

```
public class HelloApp
{
  private void hello()
  {
    System.out.println("Hello");
  }
  public static void main()
  {
    hello();
  }
}
```

Class name, part of class definition

method definitions

method call

Writing and calling Java methods

Example: Drawing a rectangle

```
public static void main()
{
  horizontal();
  vertical();
  vertical();
  horizontal();
}
private void horizontal()
{ out.println("********"); }

private void vertical()
{ out.println("*------*"); }
```

method calls (the four calls inside main)

method definitions (horizontal and vertical)

Methods in the Java language

- A *method call* statement invokes the method and passes parameters to it
- Method calls always follow an object or class name, and a dot
- A *method definition* spells out the method's executable code and local variables
- A method definition has a *header* (access specifier; type; method ID; parameters in parentheses) and a *body* (block or compound statement)

Guidelines for writing subprograms

- A method has a single purpose
- Its purpose is documented in a comment at the top
- Code longer than a page is usually broken down into methods
- Experienced programmers avoid *side effects* (e.g., output, modification of instance variables), respect class *interfaces*

3. Parameters and return values

- A *parameter* is a value passed to a method by the method's call
- A *return value* is passed from a method to the statement that calls it

Local variables

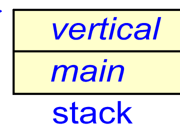
```
int quantity = 2;

void add()
{
  int sum = 2 * quantity;
  out.println("sum = " + sum);
}

public static void main()
{
  add();
}
```

Class member (instance variable): accessible to all methods in class

Local variable: accessible only in this method

Local variables and scope of access

- A variable declared within a compound statement is visible only there.
- When a method is called, an *activation record* for the call, containing local variables, is placed on top of the stack.
- When the method terminates, the stack is popped and local variables are deallocated.
- Two activation records: top →



stack

Parameters: example

```
public static void main()
{
  out.print("2 + 5 = ");
  display_sum(2,5);
}

private static
  void display_sum(int a, int b)
{
  out.print(a + b);
}
```

Actual parameters

Formal parameters

Output:
`2 + 5 = 7`

Parameters

- A way for the calling method to pass data to the called method
- Value of *actual parameter* in method call is copied to the *formal parameter* declared in called method's definition
- Formal parameter is local, is deallocated when method terminates
- Prototype must specify parameter types; definition must specify parameter names and types
- Parameters may be of any types and quantity

Parameters act like local variables

```
Private static
  void display_sum(int a, int b)
// Displays (a + b)
{
  out.print(a + "+" + b + "=");
  while (b-- > 0)  a++;
  out.print(a);
}

public static void main()
{
  int a= in.nextInt(), b= in.nextInt();
  out.print("Enter two numbers");
  display_sum(a, b);
  display_sum(6, 3);
}
```


Method return values: example

```
public void main()
{
  int age = input_age();
  out.print("You are " + age
     + " years old");
}

private static int input_age()
{
  out.print("Your age? ");
  return in.nextInt();
}
```

The value of the method call is the value used in the ***return*** *statement in the method definition.*

A return value passes data back to the calling method

- The method call is an expression
- The *return* keyword precedes the returned value in the called method
- The return value's type must be type compatible with the method's type, declared in header
- The *return* statement terminates the method call
- The returned value goes on the stack for retrieval by the calling method

sum with return value

```
public void main()
{
  out.print("Enter past due and current: ");
  int past_due=in.nextInt(),
    current=in.nextInt();
  out.print("You owe "
        + sum(past_due, current));
}

private int sum(int a, int b)
{
  return a + b;
}
```

Parameter and return-value types

Some examples:

```
private float sum(float a, float b)
{
  return (a + b);
}

private boolean is_even(int n)
{
  return (n % 2 == 0);
}

private char nth char(String s, int n)
{
  return s.charAt(n);
}
```


Stubs test a top-down design

```
public static void add()
{ out.print("Calling 'add'"); }
public static void subtract()
{ out.print("Calling 'subtract'"); }
public void main()
{
  char option;
  do {
     out.print("1 Add\n 2 Subtract\n 3 Quit");
     option=in.nextChar();
     switch (option) {
        case '1': add(); break;
        case '2': subtract(); break;
     }
  } while (option != '3');
}
```

Stub method definitions

Calls to stub methods

[*stub.cpp*]

Recursion implements a loop

```
int input_age()
// Prompts for, returns age,
// repeats until gets valid input.
{
  out.print("Age? ");
  int age = in.nextInt();
  if (age >= 0) return age;
  else return input_age();
}
```

Recursive method call

- A method that calls itself is recursive
- A *base case* (as, *age >= 0*) triggers a simple result; a recursive case triggers a recursive call
- No base case means infinite recursion

A recursive method to add

$$sum(a,b) = \begin{cases} b & \text{if } a = 0 \\ sum(a-1,\ b+1) & \text{otherwise} \end{cases}$$

```
private int sum(int a, int b)
// Returns a + b. Recursive.
{
  if (a == 0)
     return b;
  else
     return sum(a-1, b+1);
}
```

How recursion uses the stack

```
void backwards();

public void main()
{
   backwards();
}

private void backwards()
{
   char ch=in.nextChar();
   if (ch != '\n')
      backwards();
   out.print(ch);
}
```

[*backward.cpp*]

Sample I/O:
Hello
`olleH`

Questions:
How many *char* variables can store how much data? How?

Writing methods

- A method has a single purpose
- Its purpose is documented in a comment at the top
- Code longer than a page usually should be broken down
- Experienced programmers avoid side effects (e.g., output, modification of global variables)
- Methods may be tested by *driver* programs

Discussion problems

1. Write a method that returns the absolute value of the difference between two integers.
2. Convert pseudocode in Topic-5 slide, "Invariants assure correctness", to a method that prompts for 5 numbers and displays them.
3. Convert pseudocode in Topic-5 slide, "Convergence assures termination," to a method that returns the floor of the base-2 logarithm of a number.

A divide-and-conquer strategy to solve problem of walking *n* steps

```
Walk (steps)
If steps > 0
   Take a step
   Walk (steps – 1)
```

- This algorithm is *recursive* because it uses itself

4. Data abstraction and classes

- *Data abstraction* is the defining of new data types
- Some data types, whose instances have components, are called *compound*
- *Objects* are defined by their *attributes* and *operations*
- Objects are *instances of classes*
- Encapsulation separates classes' *interfaces* from their *implementations*

Enumerated types

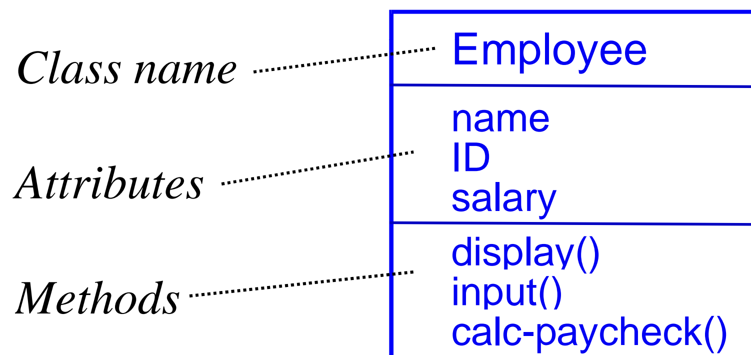
- Keyword *enum* enables definition of integer types whose values are specified by constant identifiers
- *Example:*

```
public enum Seasons
   {Spring,Summer,Fall,Winter};
Seasons this_season = Seasons.Winter;
```

Object-oriented design

- Any concept is a candidate for a class: persons, things, places, transactions
- Relationships among classes include
  - *containment* (an address object is part of a customer object)
  - *inheritance* (scrollers and dialogs are two kinds of views)
- A class implements an abstraction; it may be instantiated by one or more objects

UML class diagrams



Objects and classes

An *object* is a compound data item whose attributes (data members or instance fields) may be of any types chosen by the programmer

- Example:

Class (data type)

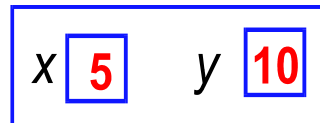
```
public class locations
{ public int x, y; };
```

- Usage:

Object (instance of class)

```
locations loc;
loc.x = 5;
loc.y = 10;
```

loc



Classes

- Programmer may define a class identifier and use it to declare instances (objects)
- Member data items (also called “instance variables”) exist in memory only when we declare instances of a class
- We use object name, dot, and member name to refer to a class member:

```
out.print(loc.x);
```

Classes associate values

- An object implements the database concept of *record* or *tuple*
- *Example:*

```
public enum Team { RedSox,Yankees };
public class Game
{
   public Team home_team, visitor_team;
   public int home_score, visitor_score;
};
```

- The example associates elements of a set of teams with each other and with elements of the set of integers (scores)
- Instance: `Game g = new Game();`

Using a class without methods

```
public class Employee {
  public String name;
  public int hours;
};

public static void main()
{
  Employee emp = new Employee();
  emp.name = "Dale";
  emp.hours = 35;
  out.print(emp.name + " worked "
      + emp.hours + " hours.");
}
```

Output: `Dale worked 35 hours.`

Classes normally have methods

Class: a compound type defined by data attributes and operations

```
public class employees
{
 String name;
 int hours;
 public void display()
 { out.print(name + " " + hours); }
};
```

Object: an instance of a class

```
employees emp1,emp2;
```


A class with methods

```
public class Employee
{
  char name[40];
  int hours;
  void input() {
    out.print("Enter name, hrs: ");
    name = in.next(); hours = in.nextInt();
  }
  void display()
  { out.print(name + " worked " + hours + " hrs"); };
}
public static void main()
{
  Employee emp = new Employee();
  emp.input();
  emp.display();
}
```

Class (annotation pointing to `Employee`)

Methods (annotation pointing to `input()` and `display()`)

Instance of class (annotation pointing to `emp`)

Methods and objects

- A call to a method must name an object, using dot

```
Employee emp = new Employee();
emp.display();
```

- Methods of a class have access to the members of that class's instances

```
public void display()
{
  out.print(name + hours);
}
```


Methods that return objects

- If a method's return value is an object reference, encapsulation can be broken unless *clone* is used
- *Example:*

Incorrect:

```
public class Customer
{
   public Address get_address()
     { return address; }
}
```

Correct:

```
   public Address get_address()
   { return (Address)address.clone(); }
```

Implicit and explicit parameters

- Every method call has an implicit parameter: the object that calls the method, e.g., *System.out* in `System.out.println("Hello");`
- Explicit parameters are those listed in parentheses
- The identifier *this* in a method implementation is a reference to the implicit-parameter object

Comparing objects

- == returns *true* iff the two operands refer to the same object – not necessarily whenever the two objects have the same attribute values
- Strings should be compared using *equals()* or *compareTo()* methods of the *String* class, not ==, >, <
- Correct example, given objects *x, y*: `if (x.equals(y))…`

5. Interface and implementation

- *Interface:* public method declarations
- *Implementation:* private members and definitions of member methods
- A programmer using a class needs to know only its *interface*
- A programmer writing or maintaining a class must understand its implementation
- Interface consists of methods listed with access specifier *public*; members listed as *private* are in implementation

Encapsulation can hide members

```
public class Employee
{
public void input();
public void display();
private String name;
private int hours;
};
```

```
public static void
main()
{
  Employee emp =
   new Employee();
  emp.hours = 40;
  emp.input();
}
```

hidden (private String name; private int hours;)

valid (emp.input();)

invalid (emp.hours = 40; — struck out, marked X)

Public members are accessible from outside a class, *private members* are hidden

Accessors and mutators

- An *accessor* is a method that does not modify data members
- Accessors are used to provide member data values, or values computed from them, to calling statements
- A *mutator* is a method that does modify member data
- In the *employees* class, *get_hours* is an accessor; *set_name* is a mutator

Constructors initialize members

```
Public class Employee
{
  public Employee()
   { name = new String();
     hours = 0; }
  public Employee(String nm,int hrs);
   { name = new String(nm);
     hours = hrs; }
  public void input();
  public void display();
  private String name;
  private int hours;
};
```

default constructor

constructor with parameters

Constructors

- Take name of class
- Initialize data members
- Must be called when object is declared
- Have no return value or type
- May take parameters
- May be *overloaded*; i.e., there may be one constructor for each set of parameters the programmer desires to be able to initialize instances with

Why program with classes?

- We may model the *state* and *behavior* of what we want to represent: e.g., persons, events, collections, displayed objects
- Classes let us model the *interactions* found in the environments we work with
- Class libraries may be *reused* conveniently
- Bookseller examples: books, customers, transactions (*challenge*: define classes for them)

References

Cay Horstmann. *Big Java,* 3rd ed. Wiley, 2008, Ch. 3.

D. Keil. Defining and using methods. Classroom handout.

______ . Defining a class. Classroom handout.