19 Structuring with classes

1 Example: student register

We illustrate program design on a larger scale, including the use of nested objects and arrays of objects. The purpose of the example is to illustarte the identification and design of classes.

We want to make a program that makes a set of course registers for students attending a certain university. Input comes from the standard input (usually the keyboard) in the form of one line per student. Each line contains (in order) student number, first name, second name, and three subjects which the student is taking. Subjects are drawn from biology, chemistry, computing, maths, physics, and stats. A typical input looks like

```
986987   Bill Smith  maths stats computing
567245   Jane Kelly  stats maths biology
965428   Fred Blogs  biology stats maths
609128   Mary Wallace  biology maths computing
754926   Carol Coutts  maths stats computing
687753   Michael Moulds  maths stats biology
297635   Pat Murphy  maths stats computing
987636   Fred Flintstone  maths stats biology
639373   Sonia Dee  maths stats biology
```

Output is, for each subject with at least one student, a sorted list of the students taking that subject. Each list is sorted according to the usual phone-book ordering. A typical output looks like

```
                SUBJECT: biology

Blogs, Fred               965428
Dee, Sonia                639373
Flinstone, Fred           987636
Kelly, Jane               567245
Moulds, Michael           687753
Wallace, Mary             609128


                SUBJECT: computing

Coutts, Carol             754926
Murphy, Pat               297635
Smith, Bill               986987
```

```
Wallace, Mary            609128


              SUBJECT: maths

Blogs, Fred              965428
Coutts, Carol            754926
Dee, Sonia               639373
Flinstone, Fred          987636
Kelly, Jane              567245
Moulds, Michael          687753
Murphy, Pat              297635
Smith, Bill              986987
Wallace, Mary            609128


              SUBJECT: stats

Blogs, Fred              965428
Coutts, Carol            754926
Dee, Sonia               639373
Flinstone, Fred          987636
Kelly, Jane              567245
Moulds, Michael          687753
Murphy, Pat              297635
Smith, Bill              986987
```

To start, we identify the important concepts in the problem domain, such as

Student number	Person's name	Subject	Sets of subjects
Student	Student register	Class roll	

We can speculate how we might represent them, as follows:

Student number

A string is sufficient here, as there are sufficient operations on strings for the purpose -- reading and writing is about all that is needed. Not worth a class.

Person's name

A pair of strings suffice, one for the forename and one for the surname. (If we were not interested in sorting names, probably a single string would have sufficed.) Operations include reading, writing, comparison etc. Worth a class.

Subject

A string is sufficient to represent a subject. The only operation is probably that of reading. Not worth a class.

Set of subjects

Each student studies a set of subjects, which we can implement as an array of subjects. Operations include reading a set of three subjects, and testing whether a particular subject is included in the set. Introduce a class.

Student

A student is represented by a student number (string), a name, and a subject set, and so these will become instance variables. Operations include reading, writing, and comparison (of student names).

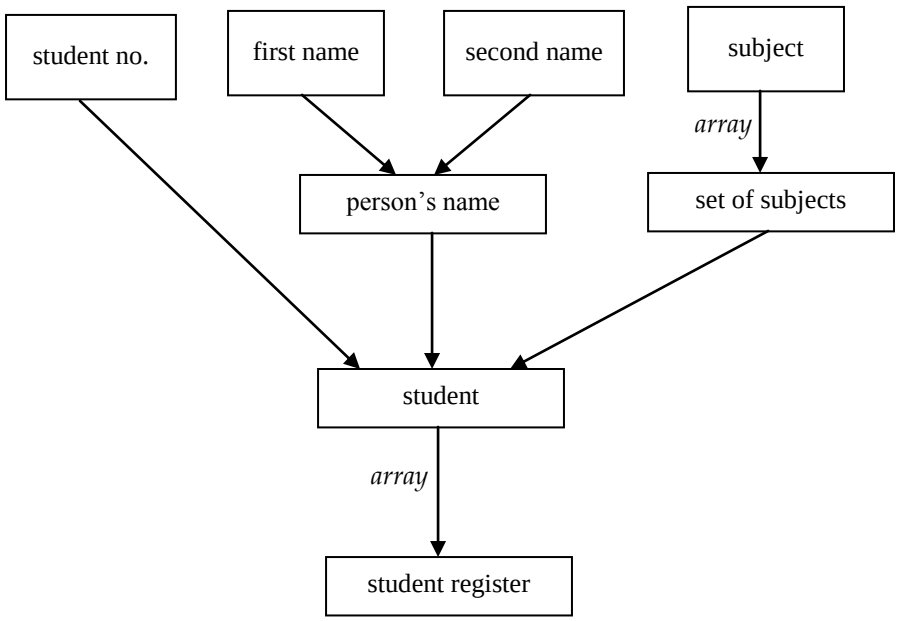
Student register

A student register is a database of all the students. We can implement it as an array of students. Operations include reading, sorting by name, et al. Introduce a class. Important: it commonly happens that we introduce a class to represent an individual item (here, a student), and a separate class to represent a collection of them (here, the student register); trying to put these notions in the same class doesn't work.

Class roll

A class roll is a list of the students taking a particular subject. There are no operations on a class roll other than to generate it from a student register, and so it will probably be convenient to do so by providing a method in the student register class.

The important components we have identified as being relevant to modeling the problem domain have a hierarchical relationship that can be depicted as follows :



We present each class in turn, highlighting some pertinent points in each. As always in these large examples, the details are not as important as the architecture.

```
class PersonName { // The name of a person

   private String first, second; // first and second names

   void get() {  // Read name from standard input
      first = Console.readToken(); second = Console.readToken();
   }

   void put() { // Write name in form "Smith, Fred" to length 25
      String name = second + ", " + first;
      System.out.printf("%-25s", name);
   }

   boolean lte(PersonName s) { // My name precedes s.name?
      return(second.compareTo(s.second)<0 ||
         (second.equals(s.second) && first.compareTo(s.first)<=0));
   }

   boolean equals(PersonName s) { // My name equals s.name?
      return(first.equals(s.first) && second.equals(s.second));
   }

}
```

Class PersonName contains nothing new that needs explanation.

```
class SubjectSet { // Set of subjects

   private final int numSubjects = 3;
   private String[] subjects = new String[numSubjects]; // The set

   void get() { // Read set from keyboard.
      for (int i=0; i<numSubjects; i++) {
         subjects[i] = Console.readToken();
```

```
    }
  }

  boolean contains(String s) { // Is s a member of the set?
    int i = 0;
    while (i<numSubjects && !subjects[i].equals(s)) i++;
    return i<numSubjects;
  }

  public final static String[] subjectTitles =
    {"biology", "chemistry", "computing", "maths", "physics", "stats"};
  public final static int numTitles = subjectTitles.length;
}
```

Observe the use of constant numSubjects: if the specification changes so that students take, say, four subjects, then only this constant needs to be changed and nothing else.

We have declared variables subjectTitles and numTitles to be static because we only need one version of each, no matter how many instances of the SubjectSet are created. Actually, the set of all possible subjects might deserve embodiment in its own class, but we have chosen to introduce it as a globally accessible array, parked for convenience within class SubjectSet.

Student numbers is another example of a concept that arguably merits its own class, but one which pragmatically we can live without. If the problem specification made more of student numbers (for example by insisting they have some special format which we should check for) then we might consider it worthwhile to make a class for them.

```
class Student { // A student

    private String studentNum;  // Student number
    private PersonName name = new PersonName(); // name
    private SubjectSet courses = new SubjectSet(); // Subjects being studied

    void get() {// Read from keyboard.
      studentNum = Console.readToken(); name.get(); courses.get();
    }

    void put() {// Display student name and number
```

```
    name.put();
    System.out.println(studentNum);
  }

  boolean lte(Student s) { // Do I precede s in phonebook order?
    return (name.lte(s.name) ||
      (name.equals(s.name) && studentNum.compareTo(s.studentNum) <=0));
  }

  boolean isTaking(String s) { // Am I taking subject s?
    return(courses.contains(s));
  }
}
```

Method isTaking() does no useful work other than passing the call to another component in the hierarchy.

```
class StudentRegister { // Register of students

  private final static int maxNumStudents= 1000;
  private Student[] register = new Student[maxNumStudents];
  private int numStudents = 0; // number of significant items in register

  void get() { // Read register of students, and sort
    while (!Console.endOfFile()) {
      register[numStudents] = new Student();
      register[numStudents].get();
      numStudents++;
    }
    sort();
  }

  private void sort() { // sort register
      // Sort register[0..numStudents-1]
      int j = 0;
      while (j<numStudents) {
        int min = j; int i = j+1;
        while (i<numStudents) {
```

```
            if (register[i].lte(register[min])) min = i;
            i++;
          }
          Student temp = register[j];
          register[j] = register[min]; register[min] = temp;
          j++;
        }
    }

    private void putHeader(String s) { // Put header for subject s
        System.out.println(); System.out.println();
        System.out.println("            SUBJECT: " + s);
        System.out.println();
    }

    void put(String s) { // Display roll for subject s
        int total = 0;  // Number of students taking this subject
        for (int i=0; i<numStudents; i++) {
            if (register[i].isTaking(s)) {
                if (total==0) putHeader(s);
                register[i].put();
                total++;
            }
        }
    }
}
```

It is attractive in this case to sort the list of students immediately after it is input.

```
class ClassRolls {
    public static void main (String[] args) {
        StudentRegister register = new StudentRegister();
        register.get();
        for (int i=0; i<SubjectSet.numTitles; i++)
            register.put(SubjectSet.subjectTitles[i]);
    }
}
```

Changes

A good test of the architecture of a program is to ask a series of questions along the lines "If the customer asked for this change, or this addition, or this generalisation, how many classes would I have to inspect, how many would I have to change, and how small would the changes be?". It is probably a bad sign if an intuitively small change in the specification leads to changes in many classes, or even to re-structuring the design. For the program above, consider the implications of small changes in the specification:

(a) Class rolls to be in order of student number.
(b) Names to be displayed in form "Bill Smith".
(c) The nationality of each student included in the input, and also in the output.
(d) Allow the number of subjects each student takes to vary.
(e) Do not assume that the possible subjects are known in advance; instead they are to be deduced from the student data.

We leave it as an exercise to show that these changes are kept fairly local to the relevant classes.