

Problem Set 4

Due: 11:59m Friday, October 15

Exam 1 Notice:

On Friday, October 15, the first take-home exam will be posted. It will be due at 11:59pm on Sunday October 24 (giving you two full weekends to work on it). **This is a hard deadline. No extensions will be given after this time.** The exam will cover the material in lecture through Lecture 10 (Wed. October 13) and the material in problem sets through PS4: iteration, recursion, arrays, vectors, immutable lists, mutable lists, enumerations, text processing, using and implementing abstract data types, and creating and testing Java programs from scratch. Because you should focus on the exam, it is **strongly** recommended that you submit PS4 on time (11:59pm Friday October 15), although you may use lateness coupons to turn in PS4 late. But since the exam is worth much more than the problem set, it might be best to cut your losses on PS4 if you are not done with it so that you can focus on the exam.

Overview:

The purpose of this assignment is to give you practice with mutable and immutable lists, sorting, and abstract data type implementations.

Working Together:

Reminder: if you worked with a partner on PS1, PS2, or PS3 and want to work with a partner on this assignment, you must choose a different partner. Please let me know if you want a partner but are having trouble finding one.

Submission:

Each team should turn in a single hardcopy submission packet for all problems by slipping it under Lyn's office door by 6pm on the due date. The packet should include:

1. a team header sheet (see the end of this assignment for the header sheet) indicating the time that you (and your partner, if you are working with one) spent on the parts of the assignment;
2. your final version of `MergeSortND.java` from Problem 1;
3. a transcript of your `MergeSortND` tests.
4. your final version of `MergeSortD.java` from Problem 2;
5. a transcript of your `MergeSortD` tests.
6. your final version of `SetCard.java` from Problem 3.
7. a transcript of your `SetCard` tests.

Each team should also submit a single softcopy (consisting of your final `ps4` directory) to the drop directory `~cs230/drop/ps4/username`, where `username` is the username of one of the team members (indicate which drop folder you used on your hardcopy header sheet). To do this, execute the following commands in Linux in the account of the team member being used to store the code.

```
cd /students/username/cs230
cp -R ps4 ~cs230/drop/ps4/username/
```

Problem 0: Merge Sort

We begin by describing **merge sort**, an algorithm used in Problems 1 and 2. We will describe how this algorithm works on lists, though the same idea can be applied to arrays and vectors.

Merge sort is a recursive algorithm, and like almost all such algorithms it can be understood in terms of divide, conquer, and glue.

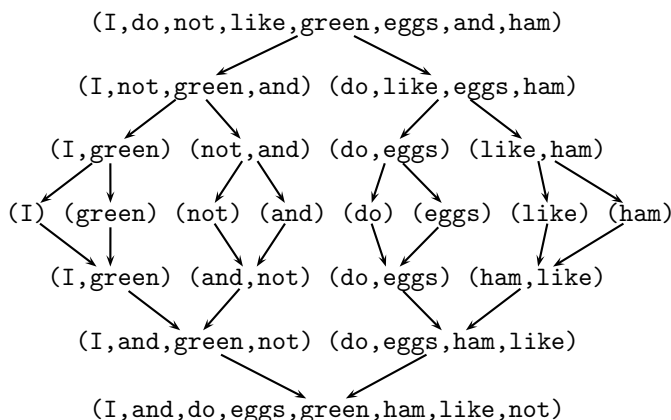
- *Divide*: In the divide step, the elements of the given list are divided up into two lists of (nearly) equal length. If the length n of the given list is even, then the resulting lists each has length $n/2$. If the length n of the given list is odd, then the resulting lists have length $(n - 1)/2$ and $((n - 1)/2) + 1$. For this algorithm, it is irrelevant how the elements are divided up. For example, here are some of the many possible ways to divide up the elements of (I,do,not,like,green,eggs,and,ham):

1. (I,do,not,like) and (green,eggs,and,ham)
2. (like,not,do,I) and (ham,and,eggs,green)
3. (I,not,green,and) and (do,like,eggs,ham)
4. (and,green,not,I) and (ham,eggs,like,do)

Although the method of splitting the original list into two nearly equal-length sublists is unimportant for the merge sort algorithm, in this assignment we will focus on an approach to splitting in which the first of the sublists is all the even-indexed elements (where 0 is the first index) in their original relative order, and the second of the sublists is all the odd-indexed elements in their original relative order. So on this assignment, the “correct” way to divide up the sample list is option (3) above.

- *Conquer*: In the conquer step, each of the two lists resulting from the divide step is recursively sorted via the same algorithm. For example, if the two lists were (I,not,green,and) and (do,like,eggs,ham), then the result of this step is the two lists (I,and,green,not) and (do,eggs,ham,like). (Uppercase letters are lexicographically less than lowercase letters, so I comes before and in sorted order.)
- *Glue*: In the glue step, the two sorted lists resulting from the conquer step are merged into a single sorted result list. In our example, this yields (I,and,do,eggs,green,ham,like,not). The merging process takes any two sorted input lists and returns a result list that has all the elements from both lists in sorted order.

For example:



Problem 1 [35]: MergeSort for Immutable Lists

On this problem, you will implement merge sort for immutable lists. Since this version of merge sort is non-destructive (in the sense that it does not change the head or tail components of any existing list node), we will use the name `MergeSortND` to name the class that holds the methods (where ND stands for “Non-Destructive”).

You should implement the following methods in the `MergeSortND` class:

Public Class Methods:

```
public static ObjectList [] split (ObjectList L);
```

Splits the elements of the given list `L` into two sublists, the first of which contains all the even-indexed elements (where indices start at 0) and the second of which contains all the odd-indexed elements. The relative order of elements in the sublists should be the same as in the original list. The two lists are returned as a two-element `ObjectList` array. For example, if `L1` is the list `(I,do,not,like,green,eggs,and,ham)`, then `split(L1)` should return an array `r` in which `r[0]` is the list `(I,not,green,and)` and in which `r[1]` is the list `(do,like,eggs,ham)`.

```
public static ObjectList merge (ObjectList L1, ObjectList L2);
```

Assume that `L1` and `L2` are lists of `Comparable` elements, possibly containing duplicates, each of which ordered from least to greatest according to the `compareTo` function. Returns a list that contains all elements (including duplicates) and in which the elements are ordered from least to greatest according to the `compareTo` function.

```
public static ObjectList sort (ObjectList L);
```

Assume that `L` is a list of `Comparable` elements. Returns a list of all the elements in `L` (possibly including duplicates) sorted from least to greatest according to the `compareTo` function. The sorting should be performed via the merge sort algorithm.

```
public static void main (String [] args);
```

If `args[0]` is `split`, tests the `split` method on the list denoted by `args[1]`. If `args[0]` is `merge`, tests the `merge` method on the list denoted by `args[1]` and `args[2]`. If `args[0]` is `sort`, tests the `sort` method on the list denoted by `args[1]`. In each case, if the string denoting the list begins with an open parenthesis, it is assumed to be the string representation of a list. But a string not beginning with an open square bracket is assumed to be the name of a file whose words are the elements of the list. Use `FileWords` (see Appendix A) to enumerate words from a file. The `../text/` directory contains a number of files that can be used as inputs. For example:

```
[lyn@w-206-198 ps4] java MergeSortND split "(I,do,not,like,green,eggs,and,ham)"
L = (I,do,not,like,green,eggs,and,ham)
ObjectList [] result = split(L);
result[0] = (I,not,green,and)
result[1] = (do,like,eggs,ham)
```

```
[lyn@w-206-198 ps4] java MergeSortND split "../text/cat-in-hat-4.txt"
L = (The,sun,did,not,shine,It,was,too,wet,to,play,So,we,sat,in,the,house,All,that,
cold,cold,wet,day)
result = split(L);
result[0] = (The,did,shine,was,wet,play,we,in,house,that,cold,day)
result[1] = (sun,not,It,too,to,So,sat,the,All,cold,wet)
```

```

[lyn@w-206-198 ps4] java MergeSortND merge "(I,and,green,not)" "(do,eggs,ham,like)"
L1 = (I,and,green,not)
L2 = (do,eggs,ham,like)
merge(L1,L2) = (I,and,do,eggs,green,ham,like,not)

[lyn@w-206-198 ps4] java MergeSortND sort "(I,do,not,like,green,eggs,and,ham)"
L = (I,do,not,like,green,eggs,and,ham)
sort(L) = (I,and,do,eggs,green,ham,like,not)

[lyn@w-206-198 ps4] java MergeSortND sort "../text/cat-in-hat-4.txt"
L = (The,sun,did,not,shine,It,was,too,wet,to,play,So,we,sat,in,the,house,All,that,
cold,cold,wet,day)
sort(L) = (All,It,So,The,cold,cold,day,did,house,in,not,play,sat,shine,sun,that,the,
to,too,was,we,wet,wet)

```

Flesh out the skeleton in `MergeSortND.java`. You may use the abbreviation `OL` for `ObjectList` and `ObjectListOps`. Feel free to implement any auxiliary methods that you find helpful.

Problem 2 [40]: MergeSort for Mutable Lists

On this problem, you will implement merge sort for mutable lists. Since this version of merge sort is destructive (in the sense that it does changes the tail components of existing list nodes), we will use the name `MergeSortD` to name the class that holds the methods (where `D` stands for “Destructive”).

You should implement the following methods in the `MergeSortD` class:

Public Class Methods:

```
public static void split (ObjectMList L);
```

Splits the elements of the given mutable list `L` into two sublists, the first of which contains all the even-indexed elements (where indices start at 0) and the second of which contains all the odd-indexed elements. The relative order of elements in the sublists should be the same as in the original list. This method should *not* create any new list nodes, nor should it change the head of any list node. It should perform all its work by modifying the tail components of list nodes. This method has `void` return type and so does not return a result. However, after the completion of `split`, the first node of the original list should be the first node of the even-indexed elements, and the second node of the original list should be the first node of the odd-indexed elements.

```
public static ObjectMList merge (ObjectMList L1, ObjectMList L2);
```

Assume that `L1` and `L2` are mutable lists of `Comparable` elements, possibly containing duplicates, each of which ordered from least to greatest according to the `compareTo` function. Returns a mutable list that contains all elements (including duplicates) and in which the elements are ordered from least to greatest according to the `compareTo` function. This method should *not* create any new list nodes, nor should it change the head of any list node. It should perform all its work by modifying the tail components of list nodes. This method returns the first node of the merged list. It should perform sorting via the merge sort algorithm.

```
public static ObjectMList sort (ObjectMList L);
```

Assume that `L` is a mutable list of `Comparable` elements. Returns a mutable list of all the elements in `L` (possibly including duplicates) sorted from least to greatest according to the `compareTo` function. This method should *not* create any new list nodes, nor should it change

the head of any list node. It should perform all its work by modifying the tail components of list nodes. This method returns the first node of the sorted list.

```
public static void main (String [] args);
```

If `args[0]` is `split`, tests the `split` method on the list denoted by `args[1]`. If `args[0]` is `merge`, tests the `merge` method on the list denoted by `args[1]` and `args[2]`. If `args[0]` is `sort`, tests the `sort` method on the list denoted by `args[1]`. In each case, the testing method should show the state of the argument lists before the method invocation and after the method invocation. If the string denoting the list begins with an open parenthesis, it is assumed to be the string representation of a list. But a string not beginning with an open square bracket is assumed to be the name of a file whose words are the elements of the list. Use `FileWords` (see Appendix A) to enumerate words from a file. The `../text/` directory contains a number of files that can be used as inputs. For example:

```
[lyn@w-206-198 ps4] java MergeSortD split "(I,do,not,like,green,eggs,and,ham)"
L = (I,do,not,like,green,eggs,and,ham)
ObjectList evens = L;
ObjectList odds = OML.tail(L);
split(L);
Before split: evens = (I,do,not,like,green,eggs,and,ham)
Before split: odds = (do,not,like,green,eggs,and,ham)
After split: evens = (I,not,green,and)
After split: odds = (do,like,eggs,ham)

[lyn@w-206-198 ps4] java MergeSortD split "../text/cat-in-hat-4.txt"
L = (The,sun,did,not,shine,It,was,too,wet,to,play,So,we,sat,in,the,house,
All,that,cold,cold,wet,day)
ObjectList evens = L;
ObjectList odds = OML.tail(L);
split(L);
Before split: evens = (The,sun,did,not,shine,It,was,too,wet,to,play,So,we,
sat,in,the,house,All,that,cold,cold,wet,day)
Before split: odds = (sun,did,not,shine,It,was,too,wet,to,play,So,we,sat,in,
the,house,All,that,cold,cold,wet,day)
After split: evens = (The,did,shine,was,wet,play,we,in,house,that,cold,day)
After split: odds = (sun,not,It,too,to,So,sat,the,All,cold,wet)

[lyn@w-206-198 ps4] java MergeSortD merge "(I,and,green,not)" "(do,eggs,ham,like)"
Before merge: L1 = (I,and,green,not)
Before merge: L2 = (do,eggs,ham,like)
merge(L1,L2) = (I,and,do,eggs,green,ham,like,not)
After merge: L1 = (I,and,do,eggs,green,ham,like,not)
After merge: L2 = (do,eggs,green,ham,like,not)

[lyn@w-206-198 ps4] java MergeSortD sort "(I,do,not,like,green,eggs,and,ham)"
Before sort: L = (I,do,not,like,green,eggs,and,ham)
sort(L) = (I,and,do,eggs,green,ham,like,not)
After sort: L = (I,and,do,eggs,green,ham,like,not)
```

```
[lyn@w-206-198 ps4] java MergeSortD sort "../text/cat-in-hat-4.txt"
Before sort: L = (The,sun,did,not,shine,It,was,too,wet,to,play,So,we,sat,
in,the,house,All,that,cold,cold,wet,day)
sort(L) = (All,It,So,The,cold,cold,day,did,house,in,not,play,sat,shine,sun,
that,the,to,too,was,we,wet,wet)
After sort: L = (The,cold,cold,day,did,house,in,not,play,sat,shine,sun,that,
the,to,too,was,we,wet,wet)
```

Flesh out the skeleton in `MergeSortD.java`. You may use the abbreviation `OML` for `ObjectMLList` and `ObjectMLListOps`. Feel free to implement any auxiliary methods that you find helpful.

Problem 3 [25]: Implementing SetCards as Integers

In lecture on Wed. October 13, we will see how the same abstract data type (ADT) can be implemented in many different ways. In particular, we will study two different implementations of the `SetCard` class from your earlier assignments. In this problem, you will define a third implementation of the `SetCard` class in `ps4/SetCard.java`.

This implementation is based on the following observation: there are precisely 81 cards in the Game of Set, so we can uniquely specify each card by a number from 0 to 80 that specifies the index the card would have in an array of lexicographically ordered cards. Fig. 1 shows the correspondence between each integer in the range 0–80 and the string representation of the card at that index.

0:1ebc	1:1ebs	2:1ebt	3:1egc	4:1egs	5:1egt	6:1erc	7:1ers	8:1ert
9:1hbc	10:1hbs	11:1hbt	12:1hgc	13:1hgs	14:1hgt	15:1hrc	16:1hrs	17:1hrt
18:1fbc	19:1fbs	20:1fbt	21:1fgc	22:1fgs	23:1fgt	24:1frc	25:1frs	26:1frt
27:2ebc	28:2ebs	29:2ebt	30:2egc	31:2egs	32:2egt	33:2erc	34:2ers	35:2ert
36:2hbc	37:2hbs	38:2hbt	39:2hgc	40:2hgs	41:2hgt	42:2hrc	43:2hrs	44:2hrt
45:2fbc	46:2fbs	47:2fbt	48:2fgc	49:2fgs	50:2fgt	51:2frc	52:2frs	53:2frt
54:3ebc	55:3ebs	56:3ebt	57:3egc	58:3egs	59:3egt	60:3erc	61:3ers	62:3ert
63:3hbc	64:3hbs	65:3hbt	66:3hgc	67:3hgs	68:3hgt	69:3hrc	70:3hrs	71:3hrt
72:3fbc	73:3fbs	74:3fbt	75:3fgc	76:3fgs	77:3fgt	78:3frc	79:3frs	80:3frt

Figure 1: Table showing the integer index of each of the 81 cards.

Based on this observation, it is possible to implement a version of the `SetCard` class in which each instance has as its single instance variable an integer `n` specifying the unique index of the card. The class should obey the same `SetCard` contract specified in PS1, a copy of which appears in Appendix B for your convenience. For example, `new SetCard(2, 'h', 'r', 'c')` should create a new `SetCard` instance whose integer instance variable is 42.

Your task in this problem is to flesh out the definition of the `SetCard` class in `ps4/SetCard.java` based on this idea. The behavior of your version of `SetCard` should be indistinguishable from that of the other representations we have studied. That is, no one using your `SetCard` implementation should have any clue that cards are being represented as integers “under the hood”.

Notes:

- The `main` method for your `SetCard` class should include testing code that shows that your methods work as advertised.
- Strive to make your method implementations as efficient as possible. For instance, one way to implement `toString` is to have a method with a *lot* of nested `if` statements, but a much better implementation uses the card index to pick the correct string out of an array of strings. Indeed, arrays are helpful for implementing many of the methods.
- Your method implementations (except for `toString` and `fromString`) should *not* convert the integer to some other representation (such as a string) and then use that other representation – that will be considered “cheating” (in a non-General-Judiciary sense ;-)).
- *Hint:* If `n` is the integer index variable, then the numbers `n%3`, `(n/3)%3`, `(n/9)%3`, and `n/27` are all interesting quantities.

Appendix A: FileWords Contract

The `FileWords` class is an implementation of the `Enumeration` interface that yields the words of a given file one by one. We shall assume that a “word” is any contiguous sequence of alphanumeric characters (i.e., letters and digits), as well as certain “special characters” – namely, `'.'`, `'-'`, `'_'`, and `'\''` (i.e., the single quote character) – that occur between two alphanumeric characters. Any other characters, including special characters touching at least one non-alphanumeric character, are not part of any word. For example, the following sentences

```
Mary-Sue -- she wouldn't use "foo_bar", 'baz!quux', or @this*that%
to name 3.141 & $17.42. Would she?
```

contain the following 16 words:

```
Mary-Sue she wouldn't use foo_bar baz quux or this that
to name 3.141 17.42 Would she
```

In addition to the `hasMoreElements` and `nextElement` instance method required by implementations of `Enumeration`, `FileWords` supports the following constructor method and `main` testing method:

```
public FileWords (String filename);
Create an enumeration that enumerates the words of the file named by filename.

public static void main (String [] args);
Invoke EnumTest.test on new FileWords(args[0]).
```

Appendix B: SetCard Contract

The `SetCard` class models a single card in the Game of Set. Such a card has four attributes, and three possible values for each attribute: (1) *number*: 1, 2, or 3; (2) *shading*: empty, filled, or hatched; (3) *color*: blue, green, or red; and (4) *shape*: circle, square, or triangle.

Public Constructor Methods:

```
public SetCard (int number, char shading, char color, char shape);
Creates a card with the specified attributes. number should be either 1, 2 or 3; shading should be either 'e' (empty), 'f' (filled) or 'h' (hatched); color should be either 'b' (blue), 'g' (green) or 'r' (red); and shape should be either 'c' (circle), 's' (square) or 't' (triangle). For example, new SetCard(2,'f','g','c') creates a card with two filled green circles. If one or more parameters is not one of the allowed values for an attribute, a RuntimeException is thrown.
```

Public Instance Methods:

```
public int number ();
Returns the number attribute of this card (either 1, 2, or 3).

public char shading ();
Returns the shading attribute of this card (either 'e' (empty), 'f' (filled), or 'h' (hatched)).
```

public char color ();

Returns the color attribute of this card (either 'b' (blue), 'g' (green), or 'r' (red)).

public char shape ();

Returns the shape attribute of this card (either 'c' (circle), 's' (square), or 't' (triangle)).

public String toString ();

Returns a string representation of this card. A string representation of a card has four characters, each of which specifies one of the four attributes of the card: the first is a digit specifying the number, the second specifies the shading, the third specifies the color, and the fourth specifies the shape. For instance "2ghs" is the string for the card that has two green hatched squares. Fig. 1 shows the string representations for all 81 cards in the Game of Set.

public boolean equals (Object x);

Returns **true** if **x** is a **SetCard** with the same four attributes as this card, and **false** otherwise.

public int compareTo (Object x);

If **x** is a **SetCard** instance, returns a negative number if this card comes before **x** in the card ordering (see the definition of card ordering below), 0 if this card is equal to **x** in the card ordering, and a positive number if this card comes after **x** in the card ordering. If **x** is not a **SetCard** instance, throws a **ClassCastException**.

The ordering on cards is defined as follows. Consider the following ordering on attributes: for numbers, $1 < 2 < 3$; for shading, empty < filled < hatched; for colors, blue < green < red; and for shapes, circle < squares < triangle. Viewing the four attributes in the order number, shading, color, and shape induces a **lexicographic ordering** (i.e., dictionary ordering) on cards in which cards are first compared by number, then by shading, then by color, and finally by shape. Fig. 1 shows the ordering of the string representation all 81 cards in the Game of Set ordered from least to greatest according to the card ordering. The ordering has been chosen so that it coincides with the lexicographic ordering of the strings representing the cards. For example, two green filled triangles is "less than" two green hatched squares because "2gft" is less than "2ghs" in dictionary order.

Public Class Methods:

public static SetCard fromString (String s);

Returns a card whose string representation is **s**. E.g., **SetCard.fromString("2ert")** returns a card with two empty red triangles. Throws a **RuntimeException** if the string **s** is not a valid string representation of a card.

CS230 Problem Set 4
Due 11:59 Friday October 15

Names of Team Members:

Date & Time Submitted:

Collaborators (*anyone you or your team collaborated with*):

By signing below, I/we attest that I/we have followed the collaboration policy as specified in the Course Information handout.

Signature(s):

*In the **Time** column, please estimate the time you or your team spent on the parts of this problem set. Team members should be working closely together, so it will be assumed that the time reported is the time for each team member. Please try to be as accurate as possible; this information will help me design future problem sets. I will fill out the **Score** column when grading your problem set.*

Part	Time	Score
General Reading		
Problem 1 [35]		
Problem 2 [40]		
Problem 3 [25]		
Total		