

CS 2210a — Data Structures and Algorithms
Assignment 4
Playing with Graphical Objects
Due Date: November 17, 11:59 pm
Total marks: 20

1 Overview

In this assignment you will write code for manipulating graphical objects, where a graphical object is just a set of pixels forming an image. We are interested in displaying the graphical objects and moving them around, detecting collisions when they occur.

The program that displays the graphical objects will receive as input a file containing a list of names of image files, each corresponding to a graphical object. The objects will be rendered on a window and the user will move some of them around using the keyboard. Graphical objects cannot overlap, so your program will allow an object to move only when its movement would not cause it to overlap with other objects or with the borders of the window. For this assignment, there will be four kinds of graphical objects:

- fixed objects, which cannot move
- objects that can be moved by the user
- objects that are moved by the computer
- target objects, that disappear when the user-controlled objects run into them.

These graphical objects will be part of a “pac-man”-like game. Objects moved by the computer will chase the user controlled ones. These latter in turn will try to get rid of the target objects. Fixed objects constrain the movement of the mobile ones.

We will provide code for reading the input file, for displaying the graphical objects and for reading the user input. You will have to write code for storing the objects and for detecting overlaps between them.

2 The Graphical Objects

As stated above, each graphical object consists of a set of pixels. Each pixel is defined by 3 values x , y , and c ; (x, y) are the coordinates of the pixel and c is its color. We will think that each graphical object f is enclosed in a rectangle r_f (so all the pixels are inside this rectangle and no smaller rectangle contains all the pixels; see Figure 1 below). The width and height of this rectangle are the width and height of the graphical object. To determine the position where an object should be displayed, we need to give the coordinates (u_x, u_y) of the upper-left corner of its enclosing rectangle; (u_x, u_y) is called the *offset* of the graphical object.

For specifying coordinates, we assume that the upper-left corner of the window ω where the graphical objects are displayed has coordinates $(0, 0)$. The coordinates of the lower-right corner of ω are (W, H) , where W is the width and H is the height of ω .

Each graphical object will have an identifier; this is just an integer number that is used to distinguish an object from another, as two objects might be identical (but they cannot be in the same position).

The pixels of a graphical object f will be stored in a binary search tree. Each node in the tree stores a data item of the form `(location,color)` representing one pixel, where `location = (x,y)` contains the coordinates of the pixel relative to the upper-left corner of the rectangle r_f enclosing the graphical object. For example, the coordinates of the black dot in Figure 1 below are $(20, 10)$, so this black dot corresponds to the pixel `((20,10),black)`. As shown in Figure 1, the offset of graphical object f_1 is $(40, 25)$, so when rendering f_1 inside the window ω the actual position of the black dot is $(20 + 40, 10 + 25) = (60, 35)$.

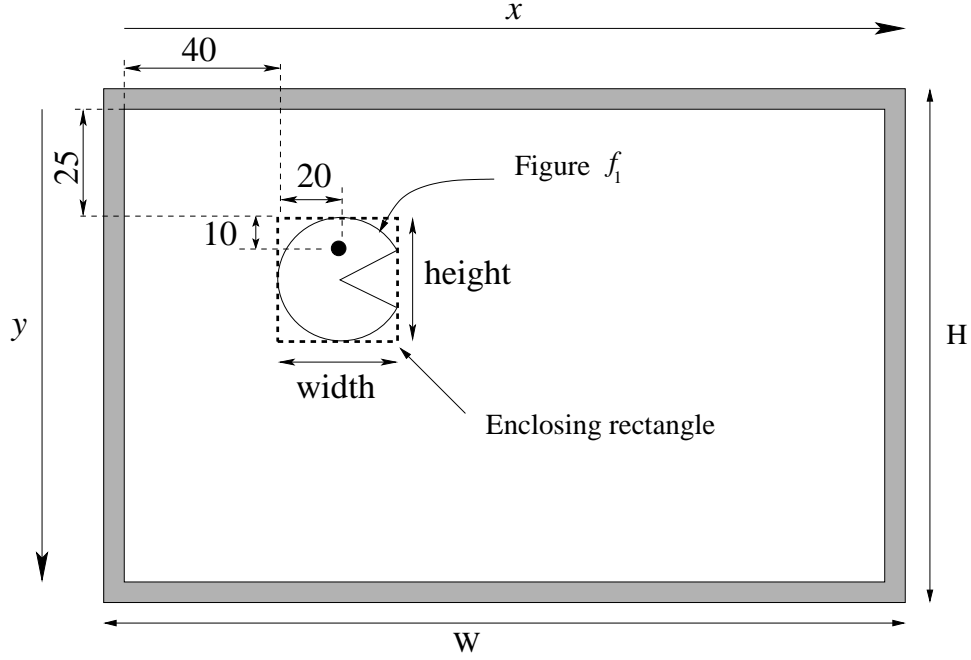


Figure 1 Window ω .

Note that by storing the pixels in the binary search tree with coordinates relative to the graphical object's enclosing rectangle, the data stored in the tree does not need to change when the graphical object moves: The only thing that needs to change is the offset of the graphical object.

For each data item `(location, color)` stored in the tree, the attribute `location` is used as the key. To compare two locations (x, y) and (x', y') we use *column order*. In column order, $(x, y) < (x', y')$ if either

- $x < x'$, or
- $x = x'$ and $y < y'$

So, for example, $(1, 4) < (2, 3)$ and $(5, 3) < (5, 7)$.

3 Moving Graphical Objects

As stated above, two graphical objects cannot overlap and an object cannot go outside the window ω . Hence, when the user tries to move an object, we need to verify that such a movement would not cause it to cross the boundaries of the window or to overlap another object.

A movement can be represented as a pair (d_x, d_y) , where d_x is the distance to move horizontally and d_y is the distance to move vertically. To check whether a movement (d_x, d_y) on graphical object f with offset (x_f, y_f) , width w_f and height h_f is valid, we first update the offset of f to $(x_f + d_x, y_f + d_y)$ and then check whether this new position for f would cause an overlap with another object or with the window's borders. To do this efficiently we proceed as follows:

- Check whether the enclosing rectangle r_f of f crosses the borders of the window ω . For example, to check whether r_f crosses the right border of ω we test if $x_f + d_x + w_f \geq W$; recall that W is the width of ω .

- If r_f does not cross the borders of ω , then we check whether r_f intersects the enclosing rectangle $r_{f'}$ of another graphical object f' . If there is no such intersection then f does not intersect other objects or the window's borders, so the movement (d_x, d_y) is valid.
- On the other hand, if r_f intersects the enclosing rectangles of some set S of graphical objects, then for each object $f' \in S$ we check whether f and f' overlap; if so, then this movement should not be allowed.

Note that for f and f' to overlap, f must have at least one pixel $((x, y), c)$ and f' must have a pixel $((x', y'), c')$ that would be displayed at precisely the same position on ω , or in other words, $x + x_f = x' + x_{f'}$ and $y + y_f = y' + y_{f'}$, where $(x_{f'}, y_{f'})$ is the offset of f' . Note that if these pixels exist then $x + x_f - x_{f'} = x'$ and $y + y_f - y_{f'} = y'$. Therefore, to test whether f and f' overlap we can use the following algorithm:

```

For each data item  $((x, y), c)$  stored in the binary search tree  $t_f$  storing the pixels of  $f$  do
    (1) if in the tree  $t_{f'}$  storing the pixels of  $f'$  there is a data item  $((x', y'), c')$  with key
         $(x', y') = (x + x_f - x_{f'}, y + y_f - y_{f'})$ , then the graphical objects overlap.
    if Condition (1) is never satisfied, then the objects do not overlap.

```

In the **for** loop above, to consider all the data items $((x, y), c)$ stored in the nodes of the tree t_f we can use the binary search tree operations `smallest()` and `successor()`.

4 Classes to Implement

You need to implement the following Java classes: `Location`, `Pixel`, `BinarySearchTree`, `BinaryNode`, `GraphicalObject`, `DuplicatedKeyException`, `InexistentKeyException`, and `EmptyTreeException`. You can implement more classes if you need to. **You must write all the code yourself.** You **cannot** use code from the textbook, the Internet, or any other sources: however, you may implement the algorithms discussed in class.

4.1 Location

This class represents the position (x, y) of a pixel. For this class you must implement all and only the following public methods:

- `public Location(int x, int y)`: A constructor that initializes the `Location` object with the specified coordinates.
- `public int xCoord()`: Returns the x coordinate of **this** `Location`.
- `public int yCoord()`: Returns the y coordinate of **this** `Location`.
- `public int compareTo (Location p)`: Compares **this** `Location` with p using column order (defined above):
 - if **this** $> p$ return 1;
 - if **this** $= p$ return 0;
 - if **this** $< p$ return -1.

You can implement any other methods that you want to in this class, but they must be declared as `private` methods (i.e. not accessible to other classes).

4.2 Pixel

This class represents the data items to be stored in the binary search tree. Each data item consists of two parts: a `Location` and an `int color`. For this class you must implement all and only the following public methods:

- `public Pixel(Location p, int color)`: A constructor which initializes the new `Pixel` with the specified coordinates and color. `Location p` is the key for the `Pixel`.
- `public Location getLocation()`: Returns the `Location` of the `Pixel`.
- `public int getColor()`: Returns the color of the `Pixel`.

You can implement any other methods that you want to in this class, but they must be declared as private methods.

4.3 BinaryNode

This class represents the nodes of the binary search tree. Each node will store an object of the class `Pixel` and it will have references to its left child, its right child, and its parent. For this class you must implement all and only the following public methods:

- `public BinaryNode (Pixel value, BinaryNode left, BinaryNode right, BinaryNode parent)`: A constructor for the class. Stores the `Pixel` in the node and sets left child, right child, and parent to the specified values.
- `public BinaryNode ()`: A constructor for the class that initializes a leaf node. The data, children and parent are set to null.
- `public BinaryNode getParent()`: Returns the parent of **this** node.
- `public void setParent(BinaryNode parent)`: Sets the parent of **this** node to the specified value.
- `public void setLeft (BinaryNode p)`: Sets the left child of **this** node to the specified value.
- `public void setRight (BinaryNode p)`: Sets the right child of **this** node to the specified value.
- `public void setData (Pixel value)`: Stores the given `Pixel` in **this** node.
- `public boolean isLeaf()`: Returns true if **this** node is a leaf; returns false otherwise.
- `public Pixel getData ()`: Returns the `Pixel` object stored in **this** node.
- `public BinaryNode getLeft()`: Returns the left child of **this** node.
- `public BinaryNode getRight()`: Returns the right child of **this** node.

You can implement any other methods that you want to in this class, but they must be declared as private methods.

4.4 BinarySearchTree

This class implements an ordered dictionary using a binary search tree. Each node of the tree will store a `Pixel` object; the attribute `Location` of the `Pixel` will be its key. In your binary search tree **only the internal nodes will store information**. The leaves are nodes (leaves are **not** null) that do not store any data.

The constructor for the `BinarySearchTree` class must be of the form

```
public BinarySearchTree()
```

This will create a tree whose root is a leaf node. Beside the constructor, the only other public methods in this class are specified in the `BinarySearchTreeADT` interface and described below. In all these methods, parameter `r` is the root of the tree.

- `public Pixel get (BinaryNode r, Location key)`: Returns the Pixel storing the given key, if the key is stored in the tree; returns null otherwise.
- `public void put (BinaryNode r, Pixel data)` throws `DuplicatedKeyException`: Inserts the given data in the tree if no data item with the same key is already there. If a node already stores the same key, the algorithm throws a `DuplicatedKeyException`.
- `public void remove (BinaryNode r, Location key)` throws `InexistentKeyException`: Removes the data item with the given key, if the key is stored in the tree; throws an `InexistentKeyException` otherwise.
- `public Pixel successor (BinaryNode r, Location key)`: Returns the Pixel with the smallest key larger than the given one (note that the tree does not need to store a node with the given key). Returns null if the given key has no successor.
- `public Pixel predecessor (BinaryNode r, Location key)`: Returns the Pixel with the largest key smaller than the given one (note that the tree does not need to store a node with the given key). Returns null if the given key has no predecessor.
- `public Pixel smallest(BinaryNode r)` throws `EmptyTreeException`: Returns the Pixel with the smallest key. Throws an `EmptyTreeException` if the tree does not contain any data.
- `public Pixel largest(BinaryNode r)` throws `EmptyTreeException`: Returns the Pixel with the largest key. Throws an `EmptyTreeException` if the tree does not contain any data.
- `public BinaryNode getRoot()`: Returns the root of the binary search tree.

You can download `BinarySearchTreeADT.java` from the course's website. To implement this interface, you need to declare your `BinarySearchTree` class as follows:

```
public class BinarySearchTree implements BinarySearchTreeADT
```

You can implement any other methods that you want to in this class, but they must be declared as private methods.

4.5 Exception Classes

These are the classes implementing the exceptions thrown by the `insert`, `remove`, `smallest` and `largest` methods of `BinarySearchTree`. See the class notes on exceptions.

4.6 GraphicalObject

The constructor for this class must be of the form

```
public GraphicalObject (int id, int width, int height, String type, Location pos);
```

where `id` is the identifier of **this** graphical object, `width` and `height` are the width and height of the enclosing rectangle for **this** graphical object, `pos` is the offset of the object and `type` is its type. The types of the graphical objects are the following:

- "fixed": fixed graphical object
- "user": graphical object moved by the user
- "computer": graphical object moved by the computer
- "target": target graphical object.

Inside the constructor you will create an empty `BinarySearchTree` where the pixels of the graphical object will be stored.

Beside the constructor, the only other public methods in this class are specified in the `GraphicalObjectADT` interface:

- `public void setType (String type)`: Sets the type of **this** graphical object to the specified value.
- `public int getWidth ()`: Returns the width of the enclosing rectangle for **this** graphical object.
- `public int getHeight()`: Returns the height of the enclosing rectangle for **this** graphical object.
- `public String getType ()`: Returns the type of **this** graphical object.
- `public int getId()`: Returns the id of **this** graphical object.
- `public Location getOffset()`: Returns the offset of **this** graphical object.
- `public void setOffset(Location value)`: Changes the offset of **this** graphical object to the specified value
- `public void addPixel(Pixel pix)` throws `DuplicatedKeyException`: Inserts `pix` into the binary search tree associated with **this** graphical object. Throws a `DuplicatedKeyException` if an error occurs when inserting the `Pixel` into the tree.
- `public boolean intersects (GraphicalObject gobj)`: Returns `true` if **this** graphical object intersects the one specified in the parameter. It returns `false` otherwise.

You can download `GraphicalObjectADT.java` from the course's website. To implement this interface, you need to declare your `GraphicalObject` class as follows:

```
public class GraphicalObject implements GraphicalObjectADT
```

You can implement any other methods that you want to in this class, but they must be declared as `private` methods.

Hint. You might find useful to implement a method, say `findPixel(Location p)`, that returns `true` if **this** object has a pixel in location `p` and it returns `false` otherwise.

5 Classes Provided and Running the Program

The input to the program will be a file containing the descriptions of the graphical objects to be displayed. Each line of the input file contains 4 values:

```
x y type file
```

where `(x,y)` is the offset of the graphical object (these two values are integer), `type` is the type of the graphical object (this is a `String`), and `file` is the name of an image file in `.jpg`, `.bmp`, or any other image format understood by java. You will be given code for reading the input file. We specify the format of the input file just in case you want to create your own inputs.

From the course's website you can download the following classes: `Board.java`, `Gui.java`, `MoveFigure.java`, `Show.java`, `BinarySearchTreeADT.java`, and `GraphicalObjectADT.java`. The main method is in class `Show.java`. To execute the program, on a command window you will enter the command

```
java Show inputFile
```

where *inputFile* is the name of the file containing the input for the program.

6 Testing your Program

We will run a test program called `TestBST` to check that your implementation of the `BinarySearchTree` class is as specified above. We will supply you with a copy of `TestBST` to test your implementation. We will also run other tests on your software to check whether it works properly.

7 Coding Style

Your mark will be based partly on your coding style. Among the things that we will check, are

- Variable and method names should be chosen to reflect their purpose in the program.
- Comments, indenting, and white spaces should be used to improve readability.
- No variable declarations should appear outside methods (“instance variables”) unless they contain data which is to be maintained in the object from call to call. In other words, variables which are needed only inside methods, whose values do not have to be remembered until the next method call, should be declared inside those methods.
- All variables declared outside methods (“instance variables”) should be declared `private` (not `protected`), to maximize information hiding. Any access to the variables should be done with accessor methods (like `getLocation()` and `getColor()` for `Pixel`).

8 Marking

Your mark will be computed as follows.

- Program compiles, produces meaningful output: 2 marks.
- `TestBST` tests pass: 5 marks.
- `GraphicalObject` tests pass: 3 marks
- Coding style: 2 marks.
- `BinarySearchTree` implementation: 5 marks.
- `GraphicalObject` program implementation: 3 marks.

9 Submitting Your Program

You must submit an electronic copy of your program using OWL. Please **DO NOT** put your files in sub-directories and **DO NOT** submit a `.zip`, `.tar` or any other compressed file with your program. Make it sure you submit all your `.java` files not your `.class` files.

Read the tutorials posted in the course’s website on how to configure Eclipse to read command line arguments.

When you submit your program, we will receive a copy of it with a datestamp and timestamp. If you submit your program more than once please send me an email message to let me know. We will take the latest program submitted as the final version, and will deduct marks accordingly if it is late.