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Chapter 18

Mouse, Keyboard, Sounds, and Images

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18.1 Prologue

JVM (Java Virtual Machine) has a “virtual” mouse that rolls on an x-y plane and has up to three buttons. Mouse coordinates are actually the graphics coordinates of the mouse cursor; they are in pixels, relative to the upper-left corner of the component that registers mouse events. Mouse events can be captured by any object designated as a MouseListener (that is, any object of a class that implements the MouseListener interface).

Keyboard events can be captured by any object designated as a KeyListener. Handling keyboard events in an object-oriented application is complicated by the fact that a computer has only one keyboard and different objects need to listen to it at different times. There is a fairly complicated system of passing the focus (the primary responsibility for processing keyboard events) from one component to another and of passing keyboard events from nested components up to their “parents.” Handling mouse events is easier than handling keyboard events because the concept of “focus” does not apply.

In this chapter we will discuss the technical details of handling the mouse and the keyboard in a Java GUI application. We will also learn how to load and play audio clips and how to display images and icons.

18.2 Mouse Events Handling

The MouseListener interface defines five methods: mousePressed, mouseReleased, mouseClicked, mouseEntered, and mouseExited. Each of these methods receives one parameter, a MouseEvent. If e is a MouseEvent, e.getX() and e.getY() return the x and y coordinates of the event, relative to the upper-left corner of the component (usually a panel) whose listener captures the event. The getButton method returns one int value: MouseEvent.NOBUTTON, MouseEvent.BUTTON1, MouseEvent.BUTTON2, or MouseEvent.BUTTON3, depending on which, if any, of the mouse buttons has changed state.

You add a mouse listener to a component by calling the component’s addMouseListener method. It is often convenient to make a panel its own mouse listener. To do that, the panel’s constructor can call addMouseListener(this). We’ve done that in JM\Ch16\Puzzle\Puzzle.java. A mouse listener can be also implemented as a private inner class.
A class that implements the `MouseMotionListener` interface has `mouseMoved` and `mouseDragged` methods for processing events that report changes in the mouse coordinates without a change in the button state. These methods are used together with `MouseListener` methods. `mouseMoved` is called when the mouse is moved with its button up; `mouseDragged` is called when the mouse is moved with its button held down.

As you know, implementing a Java interface requires the programmer to implement each method in the interface, even those that are never used. In our `Puzzle` program, for example, only the `mousePressed` method of the mouse listener interface is used — the remaining four are empty. To eliminate these empty methods, Java designers came up with a `MouseAdapter` class. `MouseAdapter` implements all the `MouseListener` methods as empty methods. You can extend the adapter class, overriding only the methods you need in your `MouseListener` class. This is often done using an anonymous `inline class` (Figure 18-1).

```java
public class MyPanel extends JPanel
{
    public MyPanel() // constructor
    {
        ...
        addMouseListener(new MouseAdapter()
        {
            public void mouseClicked(MouseEvent e)
            {
                ... // process click at e.getX(), e.getY()
            }
        });
        ...
    }
}
```

**Figure 18-1. Adding a MouseListener to a panel using MouseAdapter**

An anonymous inline class is assumed to extend the class specified in the `new` operator. In this case, the anonymous class extends `MouseAdapter`, overriding its empty `mouseClicked` method. Here the whole expression `new MouseAdapter() {...}` is passed as a parameter to the `addMouseListener` method. Unfortunately, adapter classes undo the discipline of interfaces. If, for instance, you accidentally type `mouselicked` instead of `mouseClicked`, the code will compile but mouse events won’t be processed.
18.3 Keyboard Events Handling

Any object of a class that implements the KeyListener interface can capture keyboard events. A KeyListener can be attached to any Component by calling that component’s addKeyListener method. However, before the component can process the keystrokes, it must request focus — the responsibility for handling the keyboard events. At different times different GUI components obtain focus. Some GUI components, such as buttons or text field objects, receive the focus automatically when they are clicked. Other components, such as JPanel objects, must be explicitly activated by passing the focus to them. The focus is passed to a component by calling the component’s requestFocus method.

In the Ramblecs program from Chapter 17, for example, we attached a KeyListener to the control panel:

controlPanel.addKeyListener(new RamblecsKeyboard(...));

The RamblecsKeyboard class implements KeyListener, and controlPanel is an object of the class ControlPanel, which is a subclass of JPanel. However, our controlPanel will never “hear” any keystrokes unless we call its requestFocus method.

In Ramblecs, when you click on the button or move the slider, Swing automatically shifts keyboard focus to that component, because the button and the slider normally process keystrokes in their own way (for instance, a JButton is programmed to be activated by the spacebar, and a JSlider responds to cursor keys). If you want controlPanel get the focus back, the button listener’s actionPerformed and the slider listener’s stateChanged has to call controlPanel’s requestFocus.

The KeyListener interface specifies three methods: keyPressed, keyReleased, and keyTyped. Each of these methods receives one parameter, KeyEvent e. The KeyEvent class distinguishes “character keys,” such as letters, digits, and so on, from “action keys,” such as cursor keys, function keys, <Enter>, and so on. Action keys do not have characters associated with them. These keys are identified by their “virtual codes.” These virtual codes are defined as public static int constants in the KeyEvent class. Table 18-1 shows the names of several commonly used action keys. The VK prefix stands for “virtual key.” For instance, KeyEvent.VK_LEFT refers to the left-arrow cursor key.
18.3 ~ Keyboard Events Handling

<table>
<thead>
<tr>
<th>VK_F1 through VK_F24</th>
<th>Function keys</th>
</tr>
</thead>
<tbody>
<tr>
<td>VK_LEFT, VK_RIGHT, VK_UP, VK_DOWN</td>
<td>Cursor arrow keys</td>
</tr>
<tr>
<td>VK_KP_LEFT, VK_KP_RIGHT, VK_KP_UP, VK_KP_DOWN</td>
<td>Cursor arrow keys on the numeric keypad</td>
</tr>
<tr>
<td>VK_HOME, VK_END, VK_PAGE_UP, VK_PAGE_DOWN, etc.</td>
<td>As implied by the names</td>
</tr>
</tbody>
</table>

Table 18-1. KeyEvent’s symbolic constants for virtual keys

The details of what happens on the keyboard, which methods are called in response, and what value is passed to them in the KeyEvent are rather technical. For instance, if you press the shift key and then ‘a’, then release ‘a’ and release shift, this will result in two calls to keyPressed, two calls to keyReleased, and one call to keyTyped.

To keep things simple, use the keyTyped method to capture characters and use either the keyPressed or keyReleased method to capture action keys. When an action key is pressed, keyTyped is not called.

In the keyTyped method, e.getKeyChar() returns the typed character. In the keyPressed and keyReleased methods, e.getKeyCode() returns the virtual code.

A KeyEvent object also has the boolean methods isShiftDown, isAltDown, and isControlDown, which return true if the respective “modifier” key was held down when the key event occurred.

A more general getModifiers method returns an integer whose individual bits, when set, represent the pressed modifier keys: Shift, Ctrl, Alt, and so on. These bits can be tested by using bit masks defined as static constants in KeyEvent.
Let’s take this opportunity to review the use of Java’s bit-wise logical operators. For example, we would use the bit-wise “and” operator to test whether a particular bit in an integer is set to 1:

```java
if ((e.getModifiers() & KeyEvent.ALT_MASK) != 0)
    // if ALT is down
...
```

Here `&` is bit-wise “and” operator: a bit in the result is set to 1 if both corresponding bits in the operands are 1. `KeyEvent.ALT_MASK` is an integer constant with only one bit set in it. The condition tests whether this bit is also set in the value returned by `getModifiers` (Figure 18-2).

![Figure 18-2. & operator used to test a particular bit in an integer](image)

You can use a combined mask to test whether two modifier keys are held down at once. For example:

```java
int mask = KeyEvent.SHIFT_MASK | KeyEvent.CTRL_MASK;
```

Here `|` is the bit-wise “or” operator: a bit in the result is set to 1 if at least one of the corresponding bits in the operands is 1. So the above statement sets both the Shift and Ctrl bits in `mask` (Figure 18-3). Then

```java
if ((e.getModifiers() & mask) == mask)
```

tests whether the two bits “cut out” by `mask` from the value returned by `getModifiers` are both set to 1 (Figure 18-4).

---

Be very careful not to misuse bit-wise operators instead of `&&` and `||` operators in boolean expressions. Bit-wise operators are allowed, but they don’t follow short-circuit evaluation rules.
18.4  Lab: Ramblecs Concluded

In this lab we return to the Ramblecs program from the previous chapter. Your task here is to write the RamblecsKeyListener class. This class implements the KeyListener interface and handles keyboard input for Ramblecs.

The constructor for RamblecsKeyListener takes two parameters: a LetterPanel whiteboard and a ControlPanel controlPanel. The table below lists the actions that RamblecsKeyListener takes in response to keystrokes.
### Key Action

<table>
<thead>
<tr>
<th>Key</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENTER</td>
<td>Calls whiteboard’s enterWord()</td>
</tr>
<tr>
<td>Spacebar</td>
<td>Calls whiteboard’s dropWord()</td>
</tr>
<tr>
<td>Left/right cursor keys or arrows on the numeric keypad</td>
<td>Calls whiteboard’s moveCubeLeft() or moveCubeRight(), respectively</td>
</tr>
<tr>
<td>Up cursor key or arrow on the numeric keypad</td>
<td>Calls whiteboard’s rotateCube(-1)</td>
</tr>
<tr>
<td>Down cursor key or arrow on the numeric keypad</td>
<td>Calls whiteboard’s rotateCube(1)</td>
</tr>
<tr>
<td>Ctrl-F</td>
<td>Calls controlPanel’s speedUp()</td>
</tr>
<tr>
<td>Ctrl-S</td>
<td>Calls controlPanel’s slowdown()</td>
</tr>
</tbody>
</table>

All other keyboard events should be ignored.

Set up a project with your RamblecsKeyListener, Ramblecs.java from your solution to the Ramblecs lab in Chapter 17, and our ramblecs.jar and .wav files from JM\Ch17\Ramblecs. Test your class.

### 18.5 Playing Audio Clips

In the original release of Java, methods for playing fragments of audio (“audio clips”) were designed for applets. Applet’s getAudioClip method can be used to load an audio file into your applet. The file can be a .wav file; some other popular formats (.au, .mid, etc.) are supported, too. The file is actually loaded only when your applet attempts to play it for the first time. You need to import Java’s AudioClip class to use this method:

```java
import java.applet.AudioClip;
```
One overloaded form of `getAudioClip` takes one parameter: the URL (or pathname) of a file. The URL must be an absolute URL. Use the forward slash to separate directories in the string that represents a path — it works on all systems.

A more convenient form of `getAudioClip` takes two parameters: the path and file names separately. In this form, you can use as the first parameter the URL returned by the applet’s method `getDocumentBase()`, which returns the path of the HTML file that runs the applet. The second parameter is usually a literal string, the file name. For example:

```java
AudioClip bells = getAudioClip(getDocumentBase(), "bells.wav");
```

Alternatively, you can use as the first parameter `getCodeBase()`, which returns the URL or path of the applet’s compiled code.

Once loaded, the clip can be played using its `play` method. For example:

```java
bells.play();
```

An application (not an applet) can use a static method `newAudioClip(URL url)` of the `Applet` class to load an audio clip. To use this method, you first need to create a URL object from the audio clip file’s name.

We find this implementation counterintuitive and inelegant: Why use `Applet`’s methods and URLs when you are working on an application? We also came across some technical problems with `AudioClip`’s `play` method: it causes occasional delays when a short sound clip is played frequently.

That’s why we created our own class, `EasySound`, for loading and playing sound clips. This class is adapted from one of the more advanced examples found in Oracle’s tutorials [1]. As you have seen in several projects and exercises, our `EasySound` is indeed easy to use. For example:

```java
EasySound chomp = new EasySound("chomp.wav");
chomp.play();
```

`EasySound.java` can be found in `JM\EasyClasses`; `EasySound.class` is also included in `JM\EasyClasses\EasyClasses.jar`. 
18.6 Working with Images

Java has two types of objects that represent images: Image and ImageIcon. Either of these objects can be created by loading a picture from an image file. The two most common formats for image files are .gif (Graphics Interchange Format, pronounced “giff”) and .jpg (Joint Photographic Experts Group, pronounced “jay-peg”) format.

You need to import java.awt.Image to use the Image class.

In an application (not an applet), the easiest way to load an image from a file is the ImageIO class’s static method read. ImageIO is part of the javax.imageio package. It can be imported into your class as follows:

```java
import javax.imageio.ImageIO;
```

The ImageIO’s read method takes a File object as a parameter. It is easy to create a File object from a given pathname. For example:

```java
File imageFile = new File("happy.jpg");
```

read throws an exception if the file does not exist, so you need to use it tentatively and catch the exception:

```java
Image picture;
try {
    picture = ImageIO.read(new File("happy.jpg"));
} catch (IOException ex)
{
    System.out.println("*** Can't load happy.jpg ***");
    System.exit(1);
}
```

You display an Image object by calling drawImage from any paint or paintComponent method. Figure 18-5 offers an example of a complete program that reads an image from a file and displays it in a window.
import java.awt.Graphics;
import java.awt.Image;
import javax.swing.JFrame;
import javax.imageio.ImageIO;
import java.io.File;
import java.io.IOException;

public class ImageTest extends JFrame
{
    private Image picture;

    public ImageTest()
    {
        super("Image Test");
        setSize(1000, 800);

        String pathname = "images/happy.jpg";
        try
        {
            picture = ImageIO.read(new File(pathname));
        }
        catch (IOException ex)
        {
            System.out.println("*** Can't load " + pathname + " ***");
            System.exit(1);
        }

    }

    public void paint(Graphics g)
    {
        super.paint(g);

        if (picture != null)
        {
            // center the picture:
            int x = (getWidth() - picture.getWidth(null)) / 2;
            int y = (getHeight() - picture.getHeight(null)) / 2;
            g.drawImage(picture, x, y, null);
        }
    }

    public static void main(String[] args)
    {
        ImageTest window = new ImageTest();
        window.setLocation(20, 20);
        window.setDefaultCloseOperation(EXIT_ON_CLOSE);
        window.setVisible(true);
    }
}
In the `drawImage` call, the first parameter is a reference to the image; the second and third are the \( x \) and \( y \) coordinates of the upper-left corner of the displayed image, relative to the component on which the image is drawn; and the fourth is a reference to an `ImageObserver` object, usually `null` or this.

```java
image.getWidth(null) and image.getHeight(null) calls return the raw dimensions of `image`.
```

If the truth be told, `ImageIO.read` actually creates a `BufferedImage` object. `BufferedImage` is a subclass of `Image`. A `BufferedImage` provides easy access to the image buffer that holds colors of individual pixels. See Java API for details.

In an applet you can use `JApplet`'s `getImage` method to load an `Image`. This method is analogous to the `getAudioClip` method discussed in the previous section. There are two forms of `getImage` that take the same kinds of parameters as `getAudioClip`: the absolute URL (or pathname) of a file, or a path and a file name as two separate parameters. In the latter form, the first parameter is often `getDocumentBase()`.

Another way to load and show an image uses the `ImageIcon` class defined in the `Swing` package. This works well in both applets and applications. An `ImageIcon` object can be constructed directly from a pathname or a URL. For example:

```java
ImageIcon coin = new ImageIcon("coin.gif");
```

In this example, the `coin.gif` file is located in the same folder as the program's code.

An `ImageIcon` can be also constructed from an `Image` object. For example:

```java
private Image coinImage;
< ... load this image, etc. >
ImageIcon coin = new ImageIcon(coinImage);
```

You can display an `ImageIcon` object by calling its `paintIcon` method from any `paint` or `paintComponent` method. See Figure 18-6 for an example.
import java.awt.Graphics;
import javax.swing.JPanel;
import javax.swing.ImageIcon;

public class IconTest extends JPanel
{
    private ImageIcon coin;

    public IconTest()
    {
        coin = new ImageIcon("coin.gif");
    }

    public void paintComponent(Graphics g)
    {
        int x = 5, y = 10;
        if (coin != null)
            coin.paintIcon(this, g, x, y);
    }
}

Figure 18-6. Drawing an ImageIcon

In the coin.paintIcon call, the first parameter is a reference to the component on which the icon is displayed; the second is a reference to the Graphics context; and the third and fourth are the x and y coordinates of the upper-left corner of the image, relative to the upper-left corner of the component on which the icon is painted.

The `getIconWidth()` and `getIconHeight()` calls return the dimensions of the icon; you can also get the icon’s image by calling its `getImage` method.

Many Swing components, including JButton, JCheckBox, JRadioButton, and JLabel, have convenient constructors and a `setIcon` method that allow you to add an icon to these components (see Appendix C).
18.7 **Lab: Slide Show**

This lab is your chance to write a small program from scratch. But first run `slideshow.jar` in the `JM\Ch18\SlideShow` folder to play with the program. It displays several images in sequence, or you can choose a particular image from a pull-down list. The program loads the images from the `images` subfolder; it assumes that all the files there are valid image files (such as `.jpg`, `.gif`, or `.bmp`). The program arranges images in the same order as they are currently arranged in the folder. The left and right arrow buttons take you to the previous or the next image in the sequence, respectively. When the beginning or the end of the sequence is reached, the program “wraps around” and shows the image from the other end. This simple program does not zoom in or zoom out; the images must be small enough to fit on the screen.

The program consists of three classes: `SlideShow`, `ControlPanel` and `ImagePanel` (Figure 18-7).

---

**Figure 18-7. Classes in the Slide Show program**

---

1. **The `SlideShow` class**

This class extends `JFrame`; its object represents the program’s window. The `SlideShow`’s constructor sets the title bar, sets the window size (by calling `JFrame`’s `setSize` method), creates a control panel and an image panel, and positions them in the window’s content pane. `SlideShow`’s `main` method creates a window, sets its initial position (by calling `JFrame`’s `setLocation` method), and makes the window visible. `SlideShow`’s `init` method, called from `main` at the end, when the window is already visible, calls `ControlPanel`’s `init`. 
2. **The ControlPanel class**

This class extends JPanel. Its constructor takes an ImagePanel and a pathname (a String) as parameters and saves their values for future use. The second parameter is the relative pathname of the folder that holds the images. In our setup, the image files are located in the images subfolder of the folder that holds the runnable program, so the relative pathname passed to the ControlPanel’s constructor will be simply "images".

The ControlPanel’s constructor can obtain a list of the file names in a given folder by calling the `list` method of the `File` object that represents the folder:

```java
File folder = new File(imageFolderPathname);
fileNames = folder.list();
if (fileNames == null || fileNames.length == 0)
{
    System.out.println("*** The folder " +
                       imageFolderPathname + " does not exist or is empty ***");
    System.exit(1);
}
```

The ControlPanel’s constructor then creates a JComboBox from the list of file names and two buttons, “reverse” and “forward”, adding the respective left- and right-arrow icons to them (the icon files are provided for you in the JM\Ch18\SlideShow folder). Don’t forget to add action listeners to these components (or the control panel itself can serve as an action listener for all three of them).

The constructor adds all three components to the panel.

The ControlPanel’s init method sets the current index of the displayed image to 0 and loads the first image:

```java
public void init()
{
    currentIndex = 0;
    imagePanel.readImage(imageFolderPathname + "/" +
                         fileNames[currentIndex]);
    imagePanel.repaint();
}
```
3. **The ImagePanel class**

This class’s constructor makes the background color of the panel white. ImagePanel’s `readImage` method takes a pathname string as a parameter. It loads the image from the file with that pathname (see Figure 18-5) and stores a reference to the image in a field, to be used later by the `paintComponent` method. `paintComponent` displays the image in the center of the panel (see Figure 18-5).

Once you get your program working, add keyboard handling to it. It is convenient to make the control panel the key listener, or use a private inner class. Define the following functions for the keys: the left and up cursor keys (regular and on the keypad) and the PageUp key work the same way as the “reverse” button; the right and down cursor keys, PageDown, Tab, Space, and Enter work the same way as the “forward” button; Home takes you back to the first image and End advances to the last image. Don’t forget to update the state of the pull-down list when a key is pressed. Make the escape key quit the program.

The difficulty here is handling the keyboard focus. You have to pass the focus to the control panel (by calling its `requestFocus` method) *after* the window has become visible. This can be done in ControlPanel’s `init` method. You also need to return the focus to the control panel after any of its components is clicked.

**18.8 Summary**

Mouse events on a component can be captured and processed by a `MouseListener` object attached to that component. A mouse listener is added to a component (usually a panel) by calling its `addMouseListener` method. It is not uncommon for a panel to be its own mouse listener or use a private inner class. A class that implements a mouse listener interface must have five methods: `mousePressed`, `mouseReleased`, and ` mouseClicked`, called upon the corresponding button action, and `mouseEntered` and `mouseExited`, called when the mouse cursor enters or leaves the component. Each of these methods takes one parameter, a `MouseEvent`. `e.getX()` and `e.getY()` return the x and y coordinates of the event in pixels, relative to the upper-left corner of the component whose listener captures it.

For more detailed mouse tracking you can use a `MouseMotionListener` which has two more methods, `mouseMoved` and `mouseDragged`. These methods are called when the mouse moves with the button up or down, respectively.
Adapter classes allow a programmer to supply only those listener methods that the program actually uses, inheriting the other (empty) methods from the adapter class.

Keyboard events can be captured and processed by a KeyListener object: an object of a class that implements the KeyListener interface and defines the keyPressed, keyReleased, and keyTyped methods. You add a key listener to a component by calling its addKeyListener method. A component must obtain “focus” by calling the requestFocus method to enable processing of keyboard events.

The keyPressed and keyReleased methods are used to process “action” keys (such as Enter, cursor keys, Home, etc.). The keyTyped method is called for “typed” keys that represent a character. Each of these three methods takes one parameter of the KeyEvent type. KeyEvent’s getKeyCode method returns the virtual code of the key, such as VK_ENTER, VK_LEFT, VK_HOME, and so on. KeyEvent’s getKeyChar method returns the typed character. KeyEvent’s boolean methods isShiftDown, isControlDown, isAltDown return true if the corresponding modifier key, Shift, Ctrl, or Alt, was held down when the event occurred. The getModifiers method returns an integer that holds a combination of bits representing the pressed modifier keys. KeyEvent has static constants defined for different modifier bits: KeyEvent.SHIFT, KeyEvent.CTRL, and so on.

You can load an audio file (a .wav file or a file in one of several other popular formats) into an applet by calling JApplet’s getAudioClip method. To play it, call AudioClip’s play method. In applications, use our EasySound class instead.

An Image object can be loaded into an application from a .gif or .jpg file (or a file in another image format) by calling ImageIO’s static method read. To display an image, call Graphics’s drawImage method.

The ImageIcon class in Swing provides another way to represent an image in your program. ImageIcon’s constructor loads an icon from a file, and ImageIcon’s paintIcon method displays the image. An ImageIcon object can be added to any JLabel, JButton, JCheckBox, or JRadioButton object.

📖 Exercises 📖
