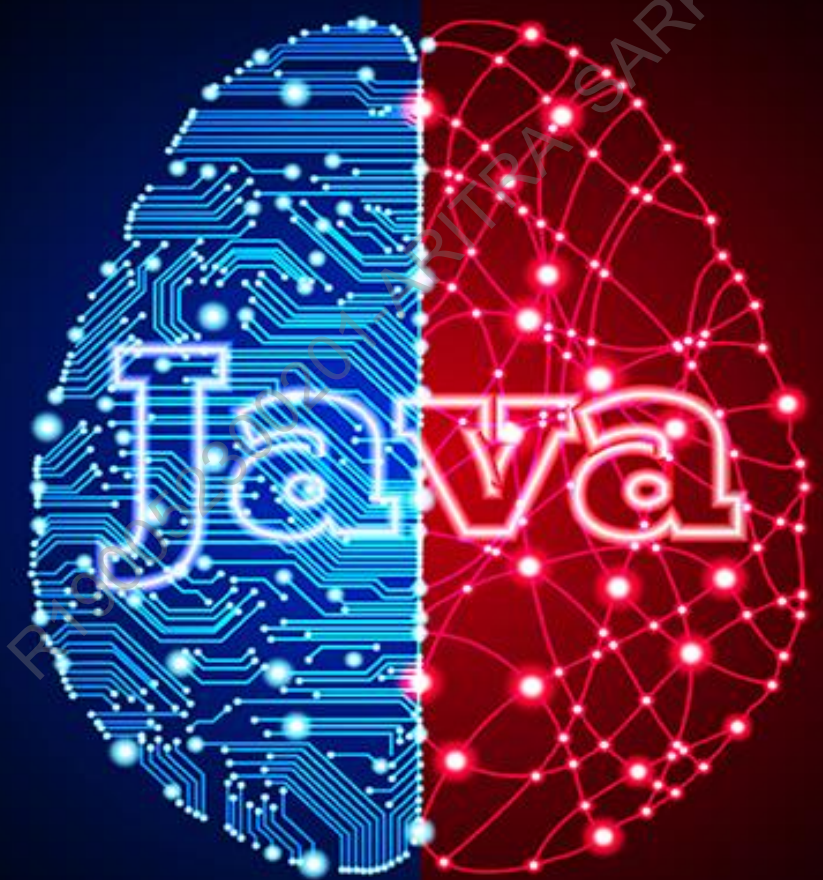
PROGRAMMING IN JAVA

Student Guide



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Programming in Java

Student Guide

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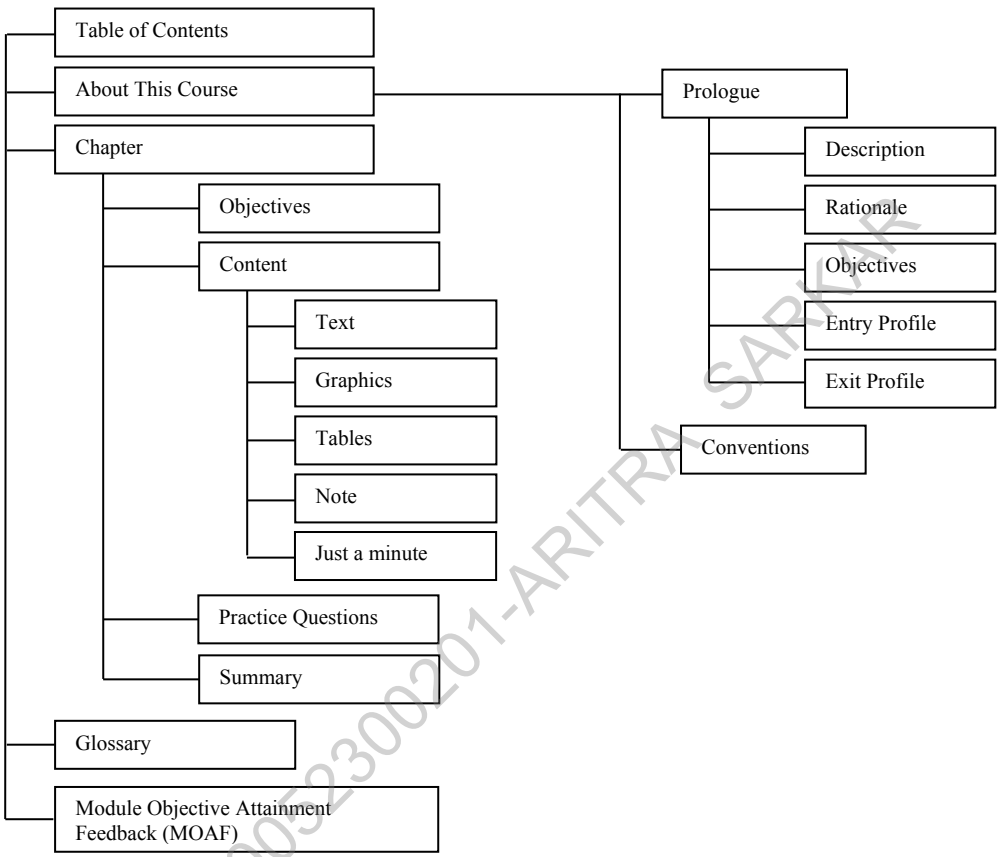
Programming in Java/SG/18-M08-V1.0

COURSE DESIGN - STUDENT GUIDE



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About This Course

Prologue

Description

The Programming in Java course helps the students to develop efficient and robust applications by using the Java programming language. It also describes how to create inner classes and generic classes. In addition, this course discusses the implementation of type casting, localization, threads, thread synchronization, and concurrency. Further, it discusses the various classes of the `java.util`, `java.io` and `java.nio` packages.

The course also explains how to work with regular expressions and how to create multithread applications. Further, it discusses the Java Database Connectivity architecture and implementation of database connectivity.

Rationale

Today, there are varied electronic devices available in the market. To work with these electronic devices, different applications are used. These applications are developed by using different programming languages, such as C, C++, Java, and C#. However, the applications developed by using programming languages like C and C++ do not support cross-platform portability.

Java is an object oriented programming language that helps to develop real-life portable applications. We can create both, CUI-based application and GUI-based application, by using Java. The code reusability feature of Java enables software developers to upgrade the existing applications without rewriting the entire code of the application.

Objectives

After completing this course, the students will be able to:

- Explore UI components
- Manage layouts
- Explore Java event model
- Implement events
- Create inner classes
- Implement localization
- Create user-defined generic classes and methods
- Implement type-safety
- Use the Set interface
- Use the List interface
- Use the Map interface
- Use the Deque interface

- Implement sorting
- Use threads in Java
- Create threads
- Implement thread synchronization
- Implement concurrency
- Get familiar with NIO
- Perform the read and write operations on a file
- Identify the layers in the JDBC architecture
- Identify the types of JDBC drivers
- Use JDBC API
- Access result sets
- Create applications using the PreparedStatement object
- Manage database transactions
- Implement batch updates in JDBC
- Create and call stored procedures in JDBC
- Use metadata in JDBC

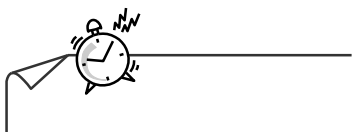
Entry Profile

The students who want to take this course should have basic knowledge of logic building and effective problem solving.

Exit Profile

After completing this course, the students will be able to develop object-based applications in Java.

Conventions

Convention	***Indicates…***
	*Note*
	*Just a minute*
	*Placeholder for an activity. The steps to complete the activity are included in the book, Programming in Java – Lab Guide.*

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Designing a User Interface and Handling Events

CHAPTER 1

An interface is the layer between a user and an application. It helps the user to interact with the application. The application can contain the Graphical User Interface (GUI) that consists of images, texts, and graphics.

To create the windows-based applications, you need to understand the features of GUI for creating an interactive and effective interface. For this, Java provides the Swing toolkit and Abstract Window Toolkit (AWT). The Swing toolkit and AWT contain the various classes and interfaces to create the GUI-based applications.

This chapter discusses how to create User Interface (UI) by using the Swing toolkit. In addition, it focuses on the various layout managers and components provided by the Swing toolkit.

GUI provides an interface through which a user interacts with the application. Therefore, it is necessary that the application must respond to the actions performed by the user. The user's actions are represented through events in the Java programming language. To handle these events, Java provides a mechanism known as event model.

An event is handled by defining and associating a handler for the event. Defining a handler enables the application to respond to the event, and associating a handler enables the application to bind the handler with the event.

This chapter discusses how to create User Interface (UI) by using the Swing toolkit. In addition, it focuses on the various layout managers and components provided by the Swing toolkit. It further focuses on the Java event model. In addition, it discusses the implementation of events.

Objectives

In this chapter, you will learn to:

- Explore UI components
- Manage layouts
- Explore Java event model
- Implement events

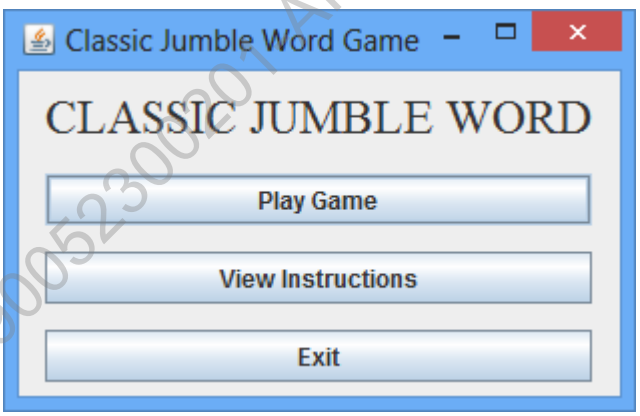
Exploring UI Components

You have created the Classic Jumble Word game. This game expects a user to enter an input, such as play game, view instructions, and exit game. The following figure shows the sample output of the Character User Interface (CUI) of the Classic Jumble Word game.

```
Please select an option from the menu
1. Play Game
2. View Instructions
3. Exit

Enter your choice:
```

The Sample Output

In a CUI application, a user needs to remember all the commands to work with the application. The user enters the commands by using the keyboard, and the application displays the result of the commands. A notification is displayed to the user if the user enters a wrong command. On the other hand, the GUI provides a graphical way of interacting with the application. The user provides an input most of the time by using a mouse and sometimes by using a keyboard. The following figure shows the GUI of the Classic Jumble Word game.

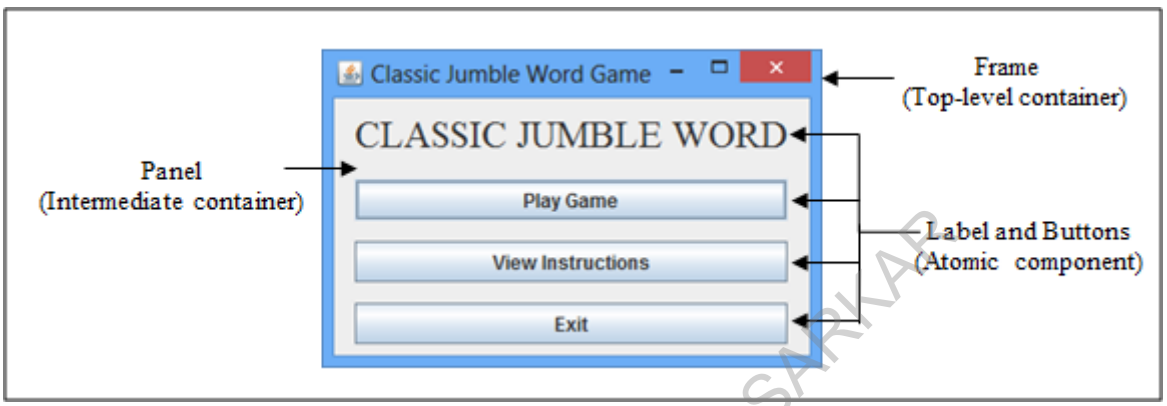


The Classic Jumble Word Game

The introduction of GUI made the application easier to learn and use. In addition, it improved the navigation and appearance of the application, which increased the productivity of the user. The features of GUI can be incorporated in the Java programs. For this, Java provides the various UI components, such as `JFrame`, `JPanel`, `JButton`, and `JLabel`, of the `javax.swing` package.

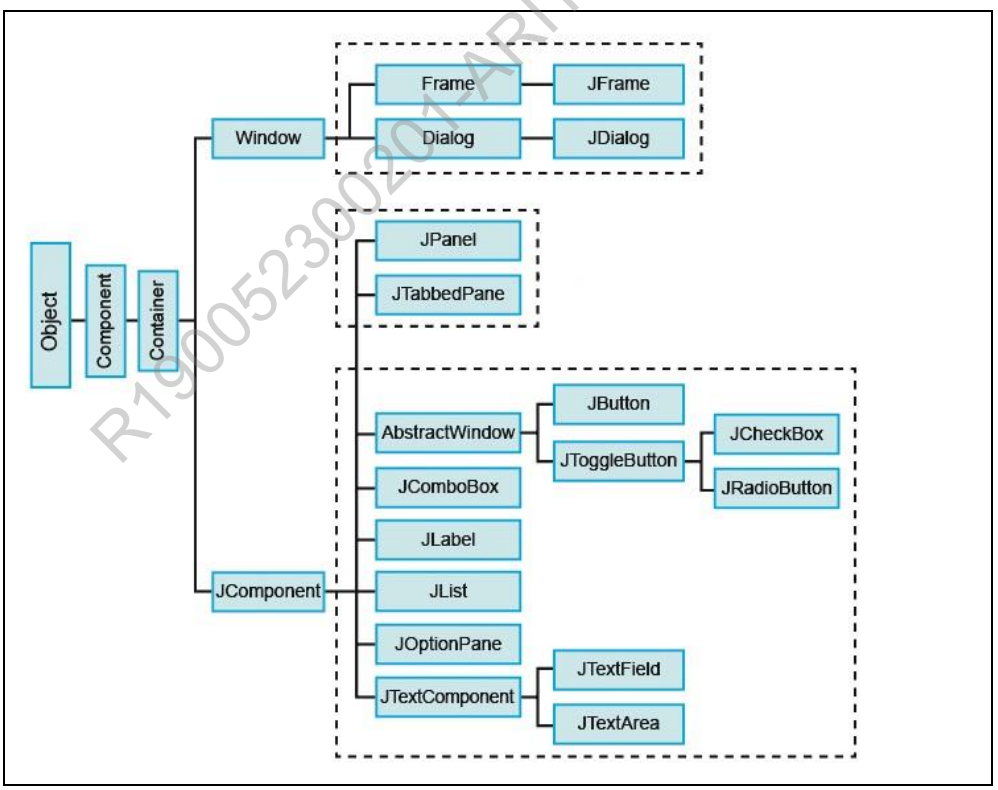
Identifying UI Components

Consider the following figure of the Classic Jumble Word game's menu screen.



The Menu Screen of the Game

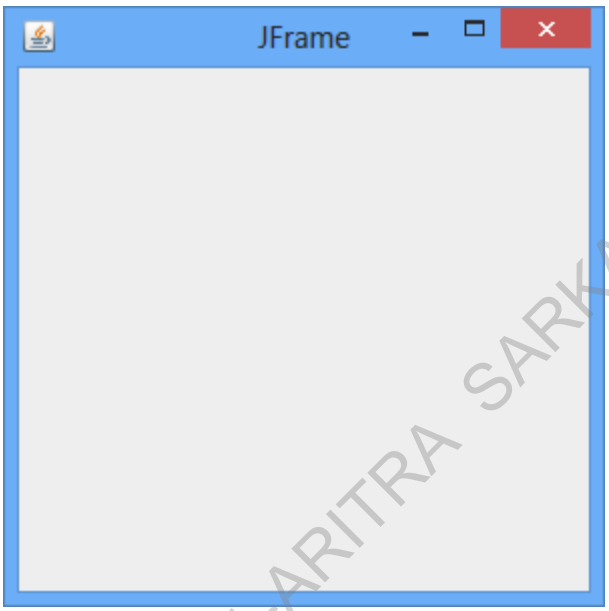
The preceding figure contains the GUI components, such as a frame, panel, label, and button. Java defines these components according to the following class hierarchy.



The Class Hierarchy

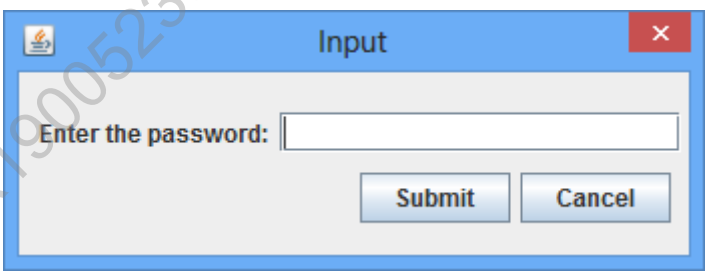
The most commonly used containers and components are:

- `JFrame`: It works as a window that is used to place other components of an application. It contains the title, border, and minimize, maximize, and close buttons. The following figure shows the `JFrame` window.



The JFrame Window

- `JDialog`: It works as a dialog box that is used to display information to the user or to prompt the user for a response. It enables you to create the modal and modeless dialog boxes. The following figure shows the Input window created using the `JDialog` class.

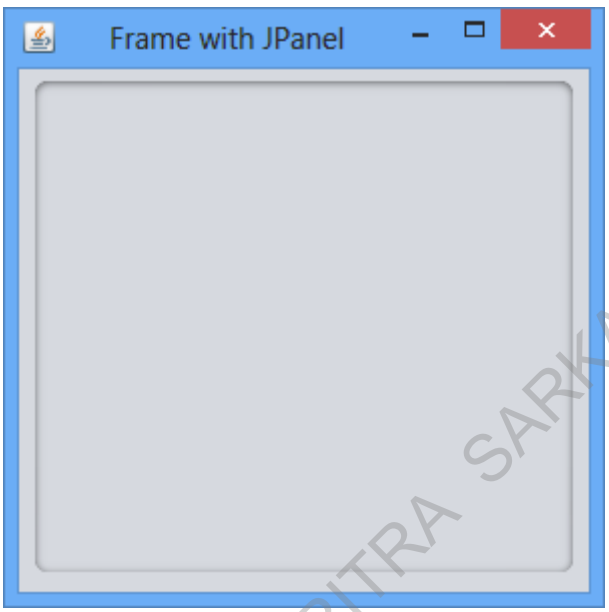


The Input Window

Note

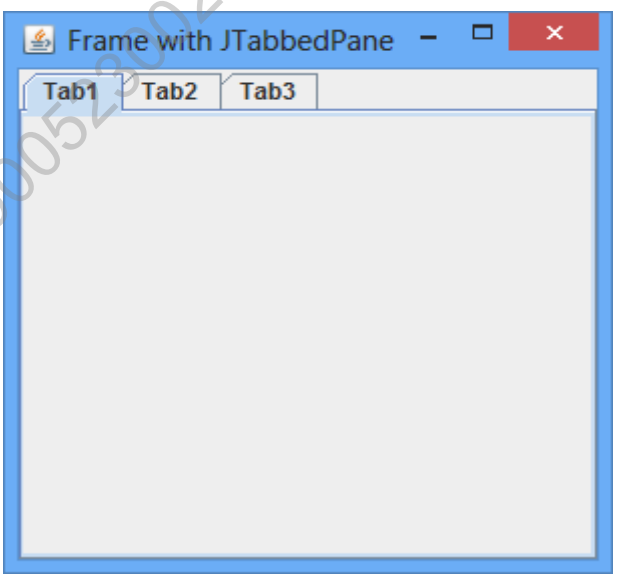
The modal dialog box does not allow you to work with other windows while the dialog box is open. Whereas, the modeless dialog box allows you to work with other windows while the dialog box is open.

- `JPanel`: It is an intermediate component that is used to organize or to group other components within a window. The following figure shows `JPanel` within the frame.



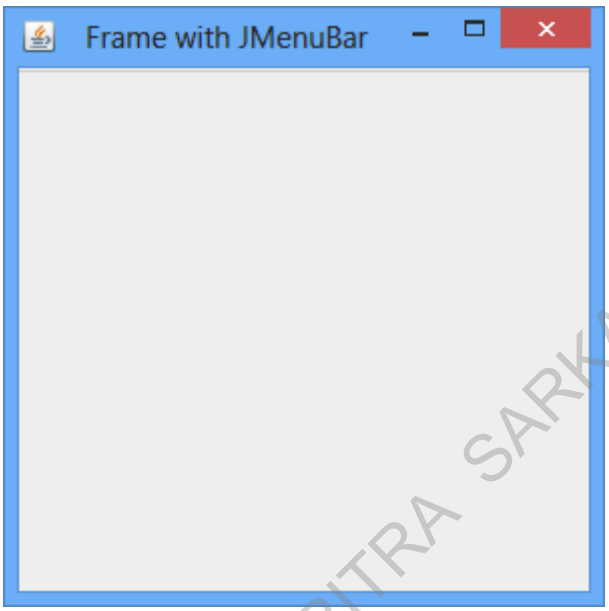
The Frame with JPanel

- `JTabbedPane`: Is used to create multiple tabbed panes. These panes can hold other components. You can switch between these panes by clicking the respective tab. The following figure shows `JTabbedPane` within the frame.



The Frame with JTabbedPane

- `JMenuBar`: Is used to display a menu bar on the frame. The following figure shows `JMenuBar` within the frame.

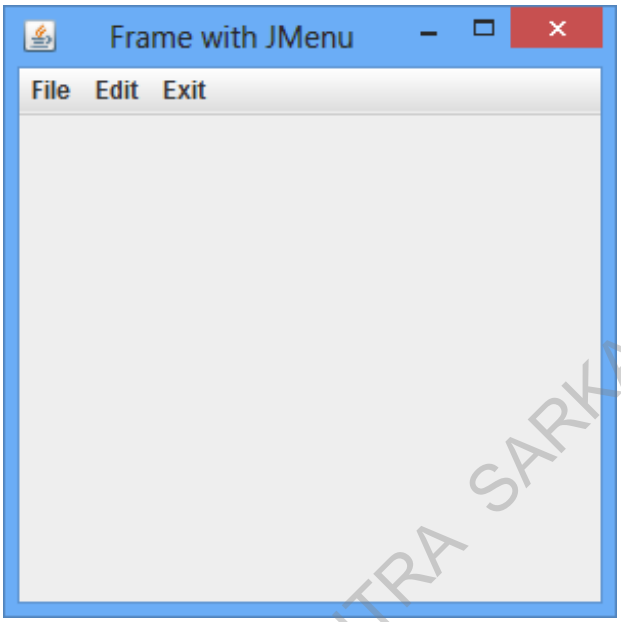


The Frame with JmenuBar

Note

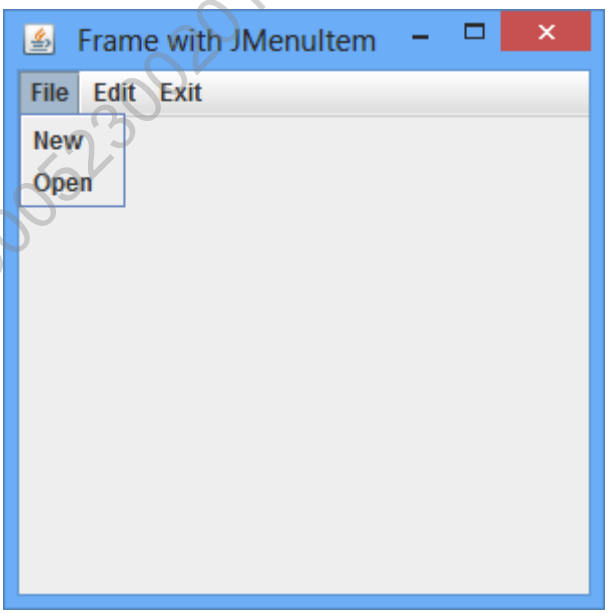
By default, a menu bar is not visible on the frame. To make it visible, you need to add the menus on the menu bar.

- `JMenu`: Is used to add the menus on the menu bar. The following figure shows `JMenu` on the menu bar.



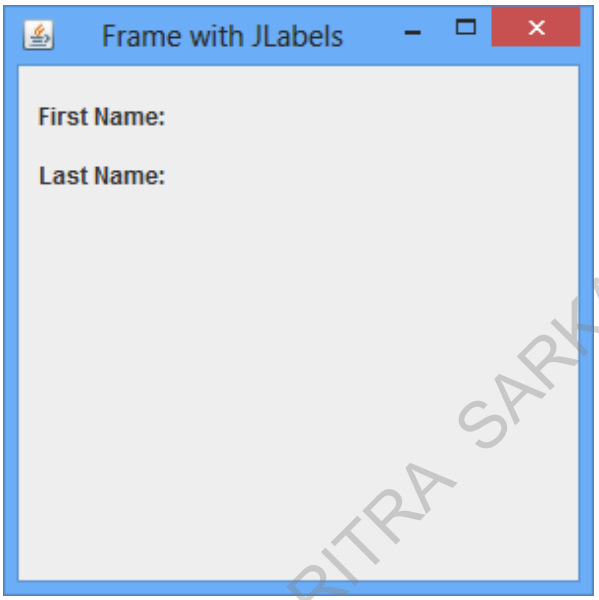
The Frame with JMenu

- `JMenuItem`: Is used to add the menu items on menu. The following figure shows `JMenuItem` of the menu.



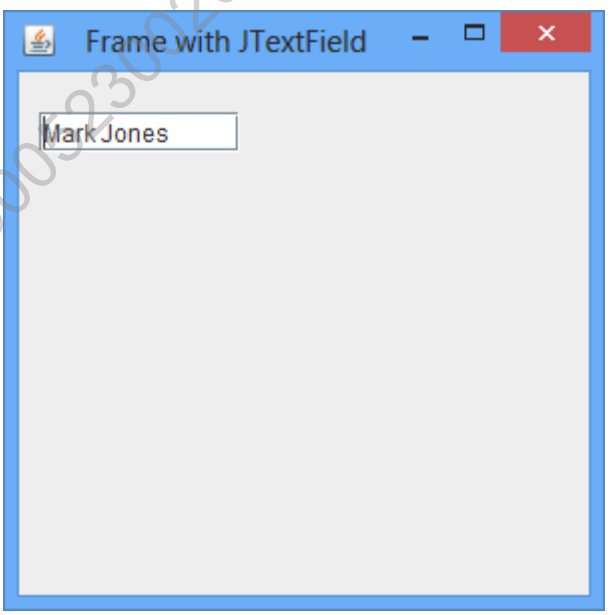
The Frame with JMenuItem

- `JLabel`: Is used to display a text or an image. By default, a label that displays the text is left aligned and a label that displays the image is horizontally cantered. The following figure shows `JLabel` within the frame.



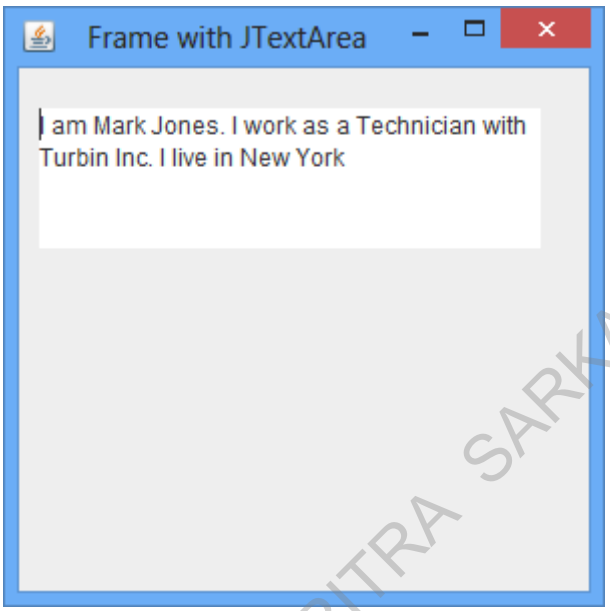
The Frame with JLabels

- `JTextField`: Is used to insert or edit a single line of text. The following figure shows `JTextField` within the frame.



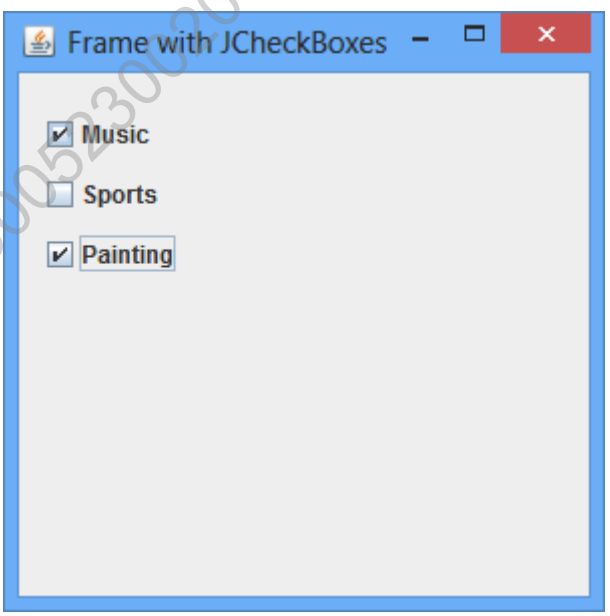
The Frame with JTextField

- `JTextArea`: Is used to insert or edit multiple lines of text. The following figure shows `JTextArea` within the frame.



The Frame with JTextArea

- `JCheckBox`: Is used to display the state of something by selecting or deselecting the check box. The following figure shows `JCheckBox` within the frame.

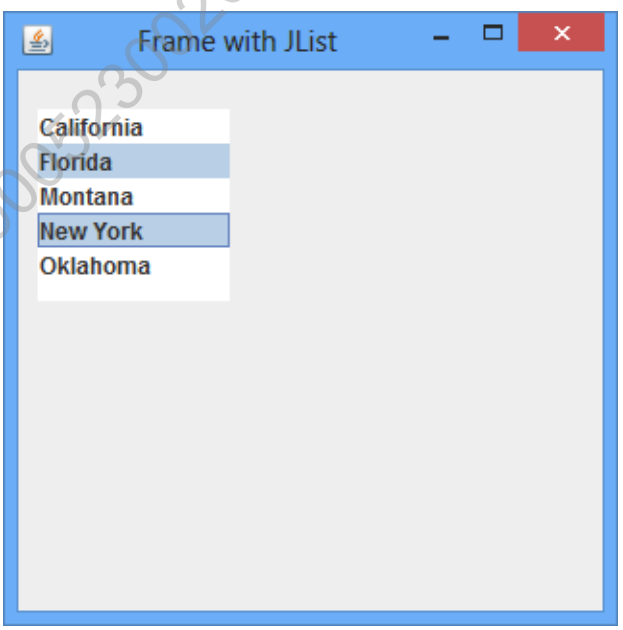


The Frame with JCheckBoxes

- `JRadioButton`: Is used to accept only one value from the predefined set of options. The following figure shows `JRadioButton` within the frame.

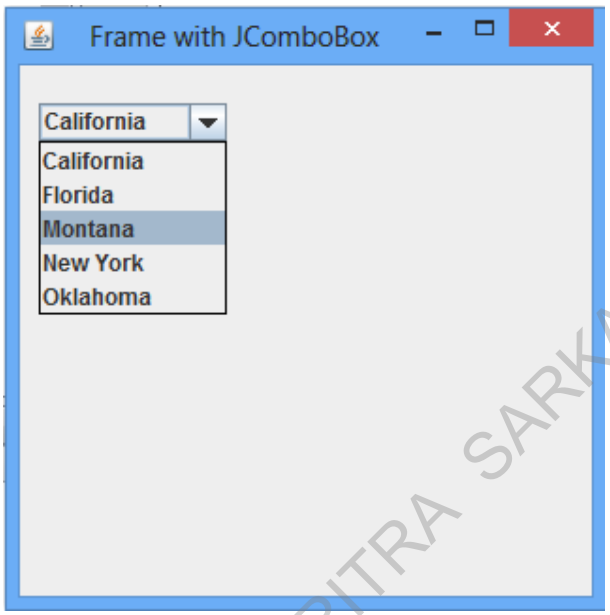
The Frame with JRadioButtons

- `JList`: Is used to provide a list of items that enables a user to select one or more items from the list. The following figure shows `JList` within the frame.



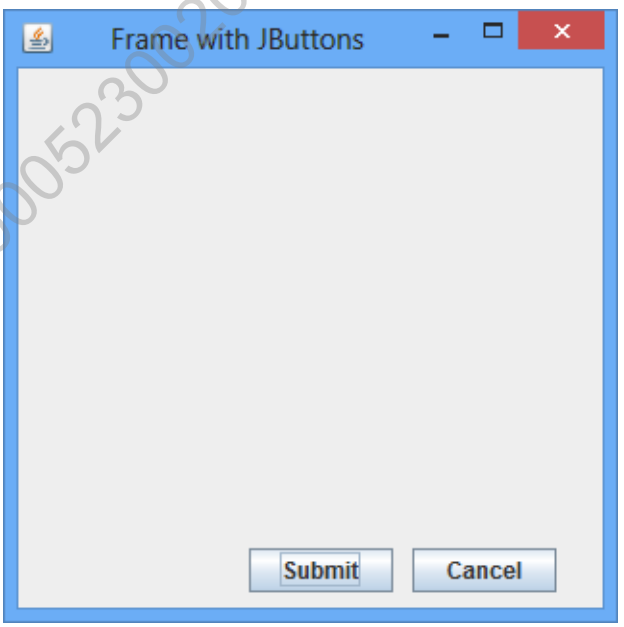
The Frame with JList

- `JComboBox`: Is used to display a combination of a text field and a drop-down list. It enables you to type or select a value from the list. The following figure shows `JComboBox` within the frame.



The Frame with JComboBox

- `JButton`: Is used to provide the clickable functionality that enables you to initiate a command. The following figure shows `JButton` within the frame.



The Frame with JButtons

- `JOptionPane`: Is used to display the dialog boxes that prompt users for a value or giving information. The following figure shows the Confirmation Message dialog box created using the `JOptionPane` class.

The Confirmation Message Dialog Box

Creating UI

Once you have identified the various Swing containers and components, you can use them to create the UI of the applications. For this, you need to import the classes and the interfaces available in the `javax.swing` package. You can create the following components:

- `JFrame`
- `JDialog`
- `JPanel`
- `JTabbedPane`
- `JMenuBar`
- `JMenu`
- `JMenuItem`
- `JLabel`
- `JTextField`
- `JTextArea`
- `JCheckBox`
- `JRadioButton`
- `JList`
- `JComboBox`
- `JButton`
- `JOptionPane`

JFrame

The following table lists the most commonly used constructors of the `JFrame` class with their description.

Constructor	***Description***
`JFrame()`	*Creates a default frame.*
`JFrame(String str)`	*Creates a default frame with the specified title.*

The Constructors of the JFrame Class

You can create `JFrame` by using the following code snippet:

```
class FrameDemo extends JFrame
{

}
```

In addition, you can create `JFrame` by using the following code snippet:

```
class FrameDemo
{
    JFrame obj;

    public FrameDemo()
    {
           obj = new JFrame();
    }
}
```

The following table lists the most commonly used methods of the `JFrame` class with their description.

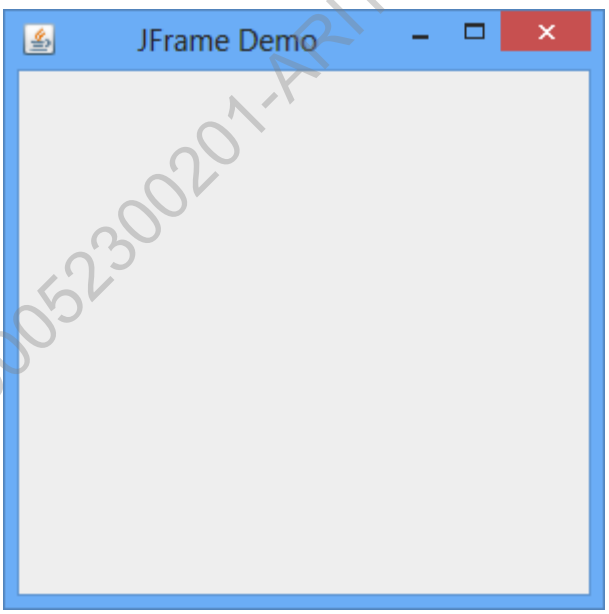
Method	***Description***
`void add(Component comp)`	*Is used to add components on the frame.*
`void setSize(int width, int height)`	*Is used to resize the frame with the specified width and height.*
`void setVisible(boolean b)`	*Is used to show or hide the frame according to the passed parameter.*
`Void setTitle(String title)`	*Is used to set the title of the frame.*

The Methods of the JFrame Class

Consider the following code to create `JFrame`:

```
import javax.swing.JFrame;

public class FrameDemo
{
    JFrame obj;

    public FrameDemo()
    {
        obj = new JFrame();
        obj.setTitle("JFrame Demo");
        obj.setVisible(true);
        obj.setSize(300,300);
    }

    public static void main(String[] args)
    {
        FrameDemo fobj = new FrameDemo();

    }
}
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the FrameDemo Class

JDialog

The following table lists the most commonly used constructors of the `JDialog` class with their description.

Constructor	***Description***
`JDialog()`	*Creates a modeless dialog box without a title.*
`JDialog(Frame owner)`	*Creates a modeless dialog box with the specified frame on which the dialog box is dependent, but without a title.*
`JDialog(Frame owner, boolean modal)`	*Creates a dialog box with the specified frame that will be set as the host of the dialog, with the type of the modality, such as modeless or modal, but without a title.*
`JDialog(Frame owner, String title)`	*Creates a modeless dialog box with the specified frame that will be set as the host of the dialog and with the specified title.*

The Constructors of the JDialog Class

You can create `JDialog` by using the following code snippet:

```
class DialogDemo extends JDialog
{

}
```

In addition, you can create `JDialog` by using the following code snippet:

```
class DialogDemo
{
    JDialog obj;

    public DialogDemo()
    {
           obj = new JDialog();
    }
}
```

The following table lists the most commonly used methods of the `JDialog` class with their description.

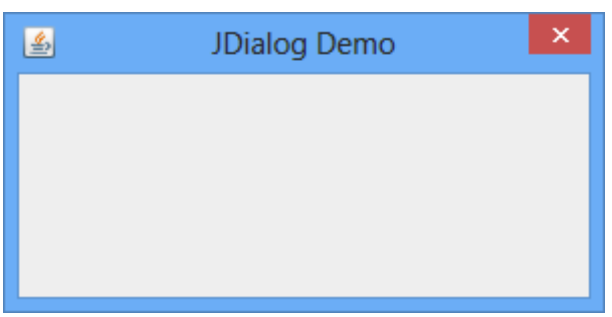
Method	***Description***
`void add(Component comp)`	*Is used to add components on the dialog box.*
`void setSize(int width, int height)`	*Is used to resize the dialog box with the specified width and height.*
`void setVisible(boolean b)`	*Is used to show or hide the dialog box according to the passed parameter.*
`void setTitle(String title)`	*Is used to set the title of the dialog box.*

The Methods of the JDialog Class

Consider the following code to create `JDialog`:

```
import javax.swing.JDialog;
public class DialogDemo
{
    JDialog obj;

    public DialogDemo()
    {
        obj = new JDialog();
        obj.setTitle("JDialog Demo");
        obj.setVisible(true);
        obj.setSize(300,150);

    }

    public static void main(String[] args)
    {
        DialogDemo dobj = new DialogDemo();

    }
}
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the DialogDemo Class

Note

To display information to the user or to prompt the user for a response, you need to design the dialog box with various components, such as a button, text field, and label, in the preceding code.

JPanel

The following table lists the most commonly used constructors of the `JPanel` class with their description.

Constructor	***Description***
`JPanel()`	*Creates an instance with a default panel.*
`JPanel(LayoutManager layout)`	*Creates an instance of a panel with the specified layout manager.*

The Constructors of the JPanel Class

You can create `JPanel` by using the following code snippet:

```
class PanelDemo extends JPanel
{

}
```

In addition, you can create `JPanel` by using the following code snippet:

```
class PanelDemo
{
    JPanel obj;
    public PanelDemo()
    {
           obj = new JPanel();
    }
}
```

The following table lists the most commonly used methods of the `JPanel` class with their description.

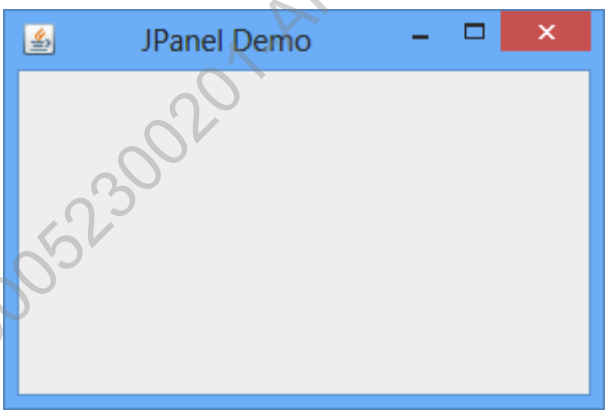
Method	***Description***
`void add(Component comp)`	*Is used to add components on the panel.*
`void setSize(int width, int height)`	*Is used to resize the panel with the specified width and height.*
`void setVisible(boolean b)`	*Is used to show or hide the panel according to the passed parameter.*

The Methods of the JPanel Class

Consider the following code to create `JPanel`:

```
import javax.swing.JFrame;
import javax.swing.JPanel;

public class PanelDemo extends JFrame
{
    JPanel obj;

    public PanelDemo()
    {
        obj = new JPanel();

        setTitle("JPanel Demo");
        setVisible(true);
        setSize(300,200);
        add(obj);
    }

    public static void main(String[] args)
    {
        PanelDemo pobj = new PanelDemo();
    }
}
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the PanelDemo Class

Note

By default, a panel is not visible on the frame. To make it visible, you need to set the properties, such as background color or border.

JTabbedPane

The following table lists the most commonly used constructors of the `JTabbedPane` class with their description.

Constructor	***Description***
`JTabbedPane()`	*Creates an instance with the default tab placement as `JTabbedPane.TOP`.*
`JTabbedPane(int tabPlacement)`	*Creates an instance with the specified tab placement, such as `JTabbedPane.TOP`, `JTabbedPane.BOTTOM`, `JTabbedPane.LEFT`, or `JTabbedPane.RIGHT`.*

The Constructors of the JTabbedPane Class

The following table lists the most commonly used methods of the `JTabbedPane` class with their description.

Method	***Description***
`void add(Component comp)`	*Is used to add components on the tabbed pane.*
`void addTab(String title, Component component)`	*Is used to add tabs on the tabbed pane.*
`void setSize(int width, int height)`	*Is used to resize the tabbed pane with the specified width and height.*
`void setVisible(boolean b)`	*Is used to show or hide the tabbed pane according to the passed parameter.*

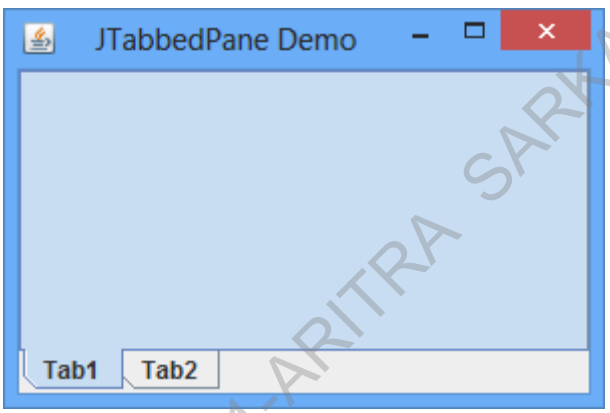
The Methods of the JTabbedPane Class

Consider the following code to create `JTabbedPane`:

```
import javax.swing.JFrame;
import javax.swing.JTabbedPane;

public class TabbedPaneDemo extends JFrame
{
    JTabbedPane obj;

    public TabbedPaneDemo()
    {
        obj = new JTabbedPane(JTabbedPane.BOTTOM);
        obj.addTab("Tab1", null);
        obj.addTab("Tab2", null);
        obj.setSize(100,100);
```

```
            this.setTitle("JTabbedPane Demo");
            this.setVisible(true);
            this.setSize(300,200);
            this.add(obj);
        }

        public static void main(String[] args)
        {
            TabbedPaneDemo tobj = new TabbedPaneDemo();
        }
    }
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the TabbedPaneDemo Class

JMenuBar

The following table lists the most commonly used constructor of the `JMenuBar` class with their description.

Constructor	***Description***
`JMenuBar`	*Creates an instance with the default menu bar.*

The Constructor of the JMenuBar Class

The following table lists the most commonly used methods of the `JMenuBar` class with their description.

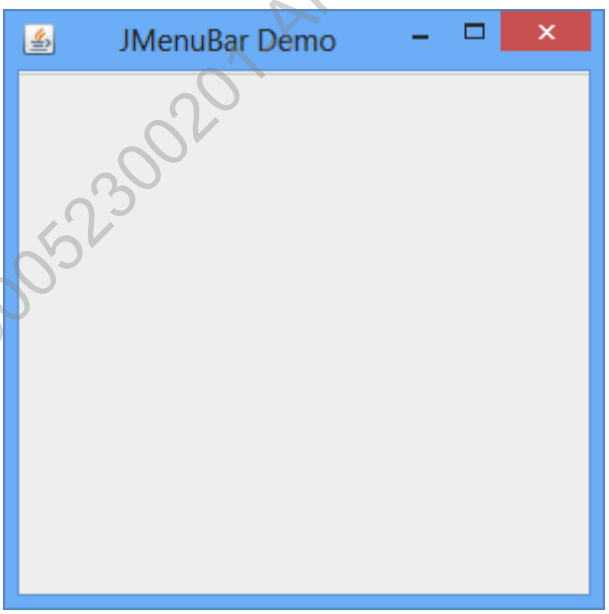
Method	***Description***
`JMenu getMenu(int index)`	*Is used to get the menu at the specified position in the menu bar.*
`int getMenuCount()`	*Is use to get the number of items in the menu bar.*

The Methods of the JMenuBar Class

Consider the following code to create `JMenuBar`:

```
import javax.swing.JFrame;
import javax.swing.JMenuBar;

public class MenuBarDemo extends JFrame
{
    JMenuBar menuBar;

    public MenuBarDemo()
    {
        menuBar=new JMenuBar();

        setJMenuBar(menuBar);
        setTitle("JMenuBar Demo");
        setSize(300, 300);
        setVisible(true);
    }

    public static void main(String[] args)
    {
        MenuBarDemo mobj = new MenuBarDemo();
    }
}
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the MenuBarDemo Class

JMenu

The following table lists the most commonly used constructors of the `JMenu` class with their description.

Constructor	***Description***
`JMenu()`	*Creates an instance with the empty text.*
`JMenu(String s)`	*Creates an instance with the specified text.*

The Constructors of the JMenu Class

The following table lists the most commonly used methods of the `JMenu` class with their description.

Method	***Description***
`Component add(Component c)`	*Is used to add a component at the end of the menu.*
`void addSeparator()`	*Is used to add a separator at the end of the menu.*

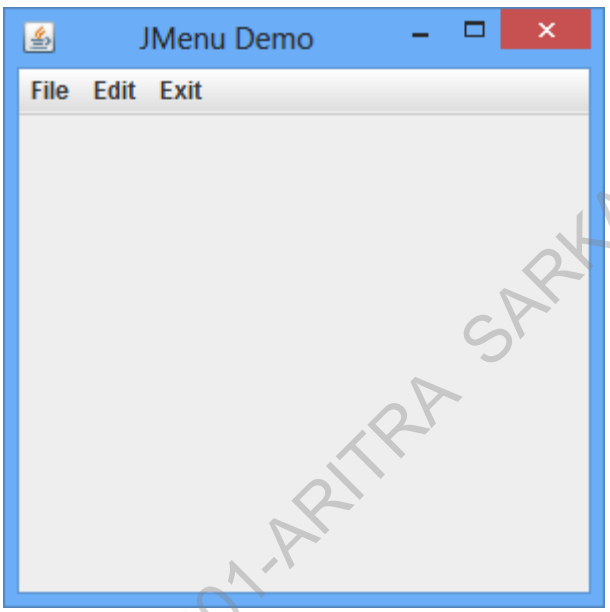
The Methods of the JMenu Class

Consider the following code to create `JMenu`:

```
import javax.swing.JFrame;
import javax.swing.JMenu;
import javax.swing.JMenuBar;

public class MenuDemo extends JFrame
{
    JMenu fileMenu, editMenu, exitMenu;
    JMenuBar menuBar;

    public MenuDemo()
    {
        menuBar = new JMenuBar();

        fileMenu = new JMenu("File");
        editMenu = new JMenu("Edit");
        exitMenu = new JMenu("Exit");

        menuBar.add(fileMenu);
        menuBar.add(editMenu);
        menuBar.add(exitMenu);

        setJMenuBar(menuBar);
        setTitle("JMenu Demo");
        setSize(300, 300);
        setVisible(true);
    }
```

```
        public static void main(String[] args)
        {
            MenuDemo mobj = new MenuDemo();
        }
    }
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the MenuDemo Class

JMenuItem

The following table lists the most commonly used constructors of the `JMenuItem` class with their description.

Constructor	***Description***
`JMenuItem()`	*Creates an instance with the empty text.*
`JMenuItem(String s)`	*Creates an instance with the specified text.*

The Constructors of the JMenuItem Class

The following table lists the most commonly used methods of the `JMenuItem` class with their description.

Method	***Description***
`void setEnabled(boolean b)`	*Is used to enable or disable the menu item.*
`void setMnemonic(int mnemonic)`	*Is used to assign the shortcut key to the menu item.*

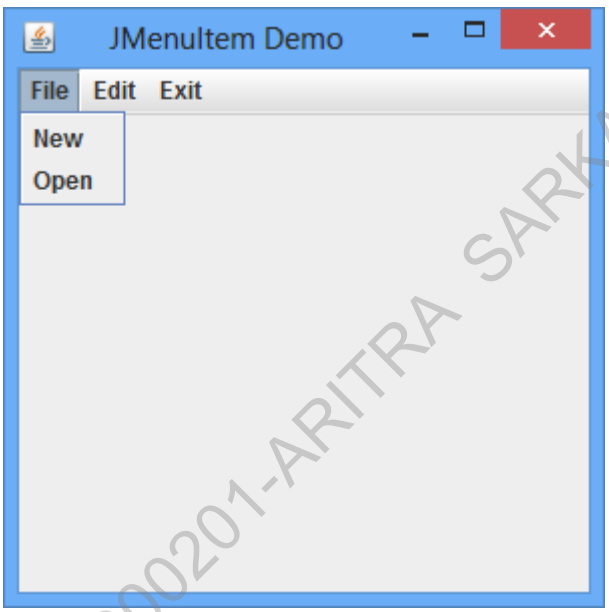
The Methods of the JMenuItem Class

Consider the following code to create `JMenuItem`:

```
import javax.swing.JFrame;
import javax.swing.JMenu;
import javax.swing.JMenuBar;
import javax.swing.JMenuItem;

public class MenuItemDemo extends JFrame
{

    JFrame menuFrame;
    JMenu fileMenu, editMenu, exitMenu;
    JMenuItem itemNew, itemOpen, itemCopy, itemPaste, itemClose;
    JMenuBar menuBar;

    public MenuItemDemo()
    {
        menuBar = new JMenuBar();

        fileMenu = new JMenu("File");
        editMenu = new JMenu("Edit");
        exitMenu = new JMenu("Exit");

        itemNew = new JMenuItem("New");
        itemOpen = new JMenuItem("Open");
        itemCopy = new JMenuItem("Copy");
        itemPaste = new JMenuItem("Paste");
        itemClose = new JMenuItem("Close");

        fileMenu.add(itemNew);
        fileMenu.add(itemOpen);
        editMenu.add(itemCopy);
        editMenu.add(itemPaste);
        exitMenu.add(itemClose);

        menuBar.add(fileMenu);
        menuBar.add(editMenu);
        menuBar.add(exitMenu);

        setJMenuBar(menuBar);
        setTitle("JMenuItem Demo");
        setSize(300, 300);
```

```
            setVisible(true);
        }

        public static void main(String[] args)
        {
            MenuItemDemo obj = new MenuItemDemo();
        }
    }
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the MenuItemDemo Class

JLabel

The following table lists the most commonly used constructors of the `JLabel` class with their description.

Constructor	***Description***
`JLabel()`	*Creates a default instance without any text.*
`JLabel(Icon image)`	*Creates an instance with the specified image.*
`JLabel(String text)`	*Creates an instance with the specified text.*

The Constructors of the JLabel Class

The following table lists the most commonly used methods of the `JLabel` class with their description.

Method	***Description***
`void setText(String text)`	*Is used to define the text that will be displayed by the label.*
`void setSize(int width, int height)`	*Is used to resize the label with the specified width and height.*
`void setVisible(boolean b)`	*Is used to show or hide the label according to the passed parameter.*

The Methods of the JLabel Class

Consider the following code to create `JLabel`:

```
import javax.swing.JFrame;
import javax.swing.JLabel;
import javax.swing.JPanel;

public class LabelDemo extends JFrame
{
    JPanel jPanel;
    JLabel firstName, lastName;

    public LabelDemo()
    {
        jPanel = new JPanel();

        firstName = new JLabel("First Name");


        lastName = new JLabel("Last Name");

        jPanel.add(firstName);
        jPanel.add(lastName);

          setTitle("JLabel Demo");
        setVisible(true);
        setSize(300,200);
        add(jPanel);

    }

    public static void main(String[] args)
    {
        LabelDemo pd = new LabelDemo();
    }
}
```

After executing the preceding code, the output is displayed, as shown in the following figure.

The Output of the LabelDemo Class

JTextField

The following table lists the most commonly used constructors of the `JTextField` class with their description.

Constructor	***Description***
`JTextField()`	*Creates an instance with empty text.*
`JTextField(String text)`	*Creates an instance with the specified text.*
`JTextField(int columns)`	*Creates an instance with the specified number of columns that is used to calculate the width of the text field.*

The Constructors of the JTextField Class

The following table lists the most commonly used methods of the `JTextField` class with their description.

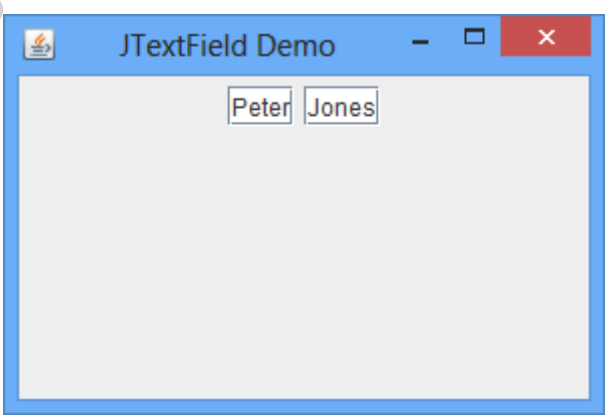
Method	***Description***
`void setText(String text)`	*Is used to define the text that will be displayed in the text box.*
`void setSize(int width, int height)`	*Is used to resize the text box with the specified width and height.*
`void setVisible(boolean b)`	*Is used to show or hide the text box according to the passed parameter.*
`String getText()`	*Is used to retrieve the text from the text box.*

The Methods of the JTextField Class

Consider the following code to create `JTextField`:

```
import javax.swing.JFrame;
import javax.swing.JPanel;
import javax.swing.JTextField;

public class TextFieldDemo extends JFrame
{
    JPanel jp;
    JTextField firstname, secondname;

    public TextFieldDemo()
    {
        jp = new JPanel();

        firstname = new JTextField();
        firstname.setText("Peter");

        secondname = new JTextField();
        secondname.setText("Jones");

        jp.add(firstname);
        jp.add(secondname);

        setTitle("JTextField Demo");
        setVisible(true);
        setSize(300,200);
        add(jp);

    }

    public static void main(String[] args)
    {
        TextFieldDemo tobj = new TextFieldDemo();
    }
}
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the TextFieldDemo Class

JTextArea

The following table lists the most commonly used constructors of the `JTextArea` class with their description.

Constructor	*Description*
`JTextArea()`	*Creates an instance with the empty text.*
`JTextArea(String text)`	*Creates an instance with the specified text.*
`JTextArea(int rows, int columns)`	*Creates an instance with the specified rows and columns.*

The Constructors of the JTextArea Class

The following table lists the most commonly used methods of the `JTextArea` class with their description.

Method	*Description*
`void setText(String text)`	*Is used to define the text that will be displayed in the text area.*
`void setSize(int width, int height)`	*Is used to resize the text area with the specified width and height.*
`void setVisible(boolean b)`	*Is used to show or hide the text area according to the passed parameter.*
`String getText()`	*Is used to retrieve the text from the text area.*

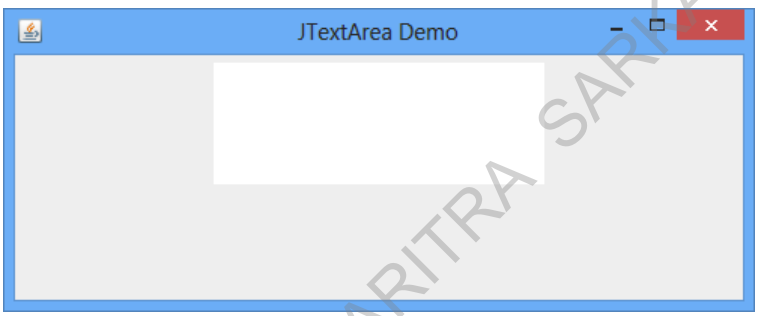
The Methods of the JTextArea Class

Consider the following code to create `JTextArea`:

```
import javax.swing.JFrame;
import javax.swing.JPanel;
import javax.swing.JTextArea;

public class TextAreaDemo extends JFrame
{
    JPanel jp;
    JTextArea about, exp;

    public TextAreaDemo()
    {
        jp = new JPanel();
        about = new JTextArea(5,20);
```

```
            jp.add(about);
            setTitle("JTextArea Demo");
            setVisible(true);
            setSize(500,200);
            add(jp);

        }

        public static void main(String[] args)
        {
            TextAreaDemo tobj = new TextAreaDemo();
        }
    }
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the TextAreaDemo Class

JCheckBox

The following table lists the most commonly used constructors of the `JCheckBox` class with their description.

Constructor	***Description***
`JCheckBox()`	*Creates an instance with the unselected check box and without any text or icon.*
`JCheckBox(String text)`	*Creates an instance with the unselected check box and with the specified text.*
`JCheckBox(Icon icon)`	*Creates an instance with the unselected check box and with the specified icon.*

The Constructors of the JCheckBox Class

The following table lists the most commonly used methods of the `JCheckBox` class with their description.

Method	***Description***
`void setText(String text)`	*Is used to define the text that will be displayed by the check box.*
`void setSize(int width, int height)`	*Is used to resize the check box with the specified width and height.*
`void setVisible(boolean b)`	*Is used to show or hide the check box according to the passed parameter.*
`String getText()`	*Is used to retrieve the text of the checkbox.*
`boolean isSelected()`	*Is used to get the state of the check box.*

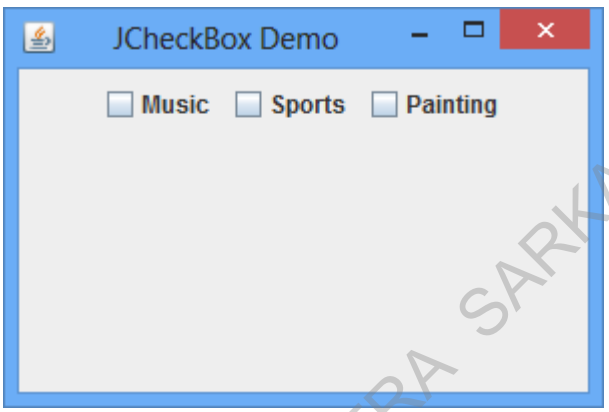
The Methods of the JCheckBox Class

Consider the following code to create `JCheckBox`:

```
import javax.swing.JCheckBox;
import javax.swing.JFrame;
import javax.swing.JPanel;

public class CheckBoxDemo extends JFrame
{
    JPanel jp;
    JCheckBox h1, h2, h3;

    public CheckBoxDemo()
    {
        jp = new JPanel();

        h1 = new JCheckBox(“Music”);
        h2 = new JCheckBox("Sports");
        h3 = new JCheckBox("Painting");

        jp.add(h1);
        jp.add(h2);
        jp.add(h3);

        setTitle("JCheckBox Demo");
        setVisible(true);
        setSize(300,200);
        add(jp);

    }
```

```
    public static void main(String[] args)
    {
        CheckBoxDemo cobj = new CheckBoxDemo();
    }

}
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the CheckBoxDemo Class

JRadioButton

The following table lists the most commonly used constructors of the `JRadioButton` class with their description.

Constructor	***Description***
`JRadioButton()`	*Creates an instance with unselected radio button without any text or icon.*
`JRadioButton(String text)`	*Creates an instance with the unselected radio button with the specified text.*
`JRadioButton(Icon icon)`	*Creates an instance with the unselected radio button with the specified icon.*

The Constructors of the JRadioButton Class

The following table lists the most commonly used methods of the `JRadioButton` class with their description.

Method	***Description***
`void setText(String text)`	*Is used to define the text that will be displayed by the radio button.*
`void setSize(int width, int height)`	*Is used to resize the radio button with the specified width and height.*
`void setVisible(boolean b)`	*Is used to show or hide the radio button according to the passed parameter.*
`String getText()`	*Is used to retrieve the text of the radio button.*
`boolean isSelected()`	*Is used to get the state of the radio button.*

The Methods of the JRadioButton Class

Consider the following code to create `JRadioButton`:

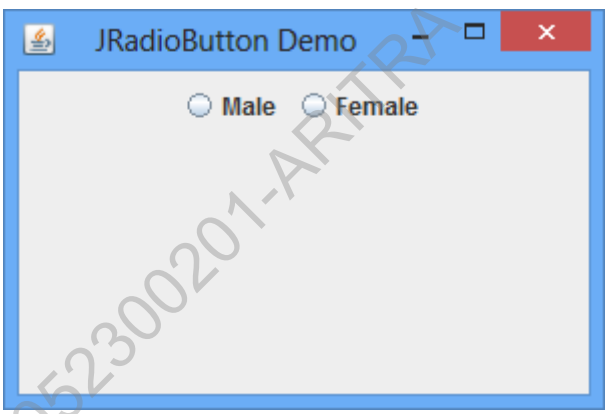
```
import javax.swing.JFrame;
import javax.swing.JPanel;
import javax.swing.JRadioButton;
import javax.swing.ButtonGroup;

public class RadioButtonDemo extends JFrame
{
    JPanel jp;
    JRadioButton male, female;
     ButtonGroup bg;

    public RadioButtonDemo()
    {
        jp = new JPanel();

        male = new JRadioButton("Male");

        female = new JRadioButton("Female");

          bg = new ButtonGroup();
         bg.add(male);
         bg.add(female);


        jp.add(male);
        jp.add(female);

        setTitle("JRadioButton Demo");
        setVisible(true);
        setSize(300,200);
```

```
            add(jp);

        }

        public static void main(String[] args)
        {
            RadioButtonDemo robj = new RadioButtonDemo();
        }

}
```

Note

`ButtonGroup` is the class that is used to group radio buttons so that only one radio button can be selected at a time.

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the RadioButtonDemo Class

JList

The following table lists the most commonly used constructors of the `JList` class with their description.

Constructor	***Description***
`JList()`	*Creates an instance with empty, read-only list.*
`JList(Object[] listData)`	*Creates an instance that displays elements in the specified array.*

The Constructors of the JList Class

The following table lists the most commonly used methods of the `JList` class with their description.

Method	***Description***
`int getSelectedIndex()`	*Is used to retrieve the index of the selected value from the list.*
`Object getSelectedValue()`	*Is used to retrieve the selected value from the list.*
`Object[] getSelectedValues()`	*Is used to retrieve the list of selected values.*
`void setSelectedIndex(int index)`	*Is used to set the selected index for the selected value in the list.*
`void setSelectedValue(Object anObject, boolean shouldScroll)`	*Is used to set the selected value in the list.*

The Methods of the JList Class

Consider the following code to create `JList`:

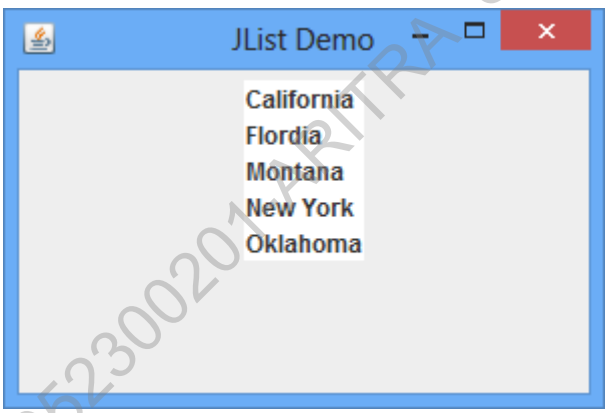
```
import javax.swing.DefaultListModel;
import javax.swing.JFrame;
import javax.swing.JList;
import javax.swing.JPanel;

public class ListDemo extends JFrame
{
    JPanel jp;
    JList list;
    DefaultListModel dlist;

    public ListDemo()
    {
        jp = new JPanel();

        list = new JList();
        list.setSelectedIndex(0);

        dlist = new DefaultListModel();
        dlist.addElement("California");
        dlist.addElement("Flordia");
        dlist.addElement("Montana");
        dlist.addElement("New York");
        dlist.addElement("Oklahoma");
        list.setModel(dlist);

        jp.add(list);

        setTitle("JList Demo");
        setVisible(true);
        setSize(300,200);
```

```
            add(jp);

        }

        public static void main(String[] args)
        {
            ListDemo lobj = new ListDemo();
        }
}
```

Note

`DefaultListModel` is a class that is used to create a default list of items. The items can be added to the default list model by using the `addElement()` method.

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the ListDemo Class

JComboBox

The following table lists the most commonly used constructors of the `JComboBox` class with their description.

Constructor	***Description***
JComboBox()	*Creates an instance with the empty list of objects.*
JComboBox(Object[] items)	*Creates an instance that contains the list of elements in the specified array.*

The Constructors of the JComboBox Class

The following table lists the most commonly used methods of the `JComboBox` class with their description.

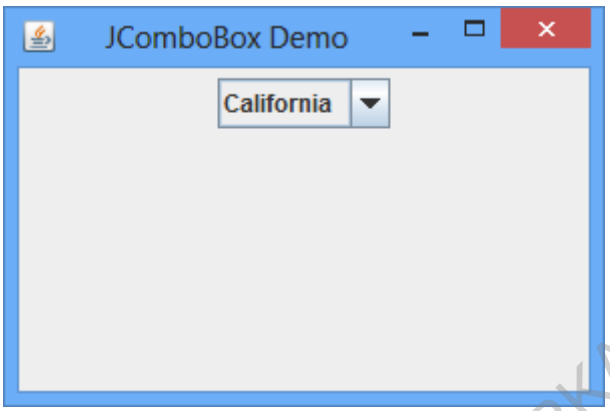
Method	***Description***
`void addItem(Object anObject)`	*Is used to add items to the list.*
`void setSize(int width, int height)`	*Is used to resize the combo box with the specified width and height.*
`void setVisible(boolean b)`	*Is used to show or hide the combo box according to the passed parameter.*
`Object getItemAt(int index)`	*Is used to retrieve the item at the specified index from the list.*

The Methods of the JComboBox Class

Consider the following code to create `JComboBox`:

```
import javax.swing.JComboBox;
import javax.swing.JFrame;
import javax.swing.JPanel;

public class ComboBoxDemo extends JFrame
{
    JPanel jp;
    JComboBox city;

    public ComboBoxDemo()
    {
        jp = new JPanel();

        city = new JComboBox();
        city.addItem("California");
        city.addItem("Florida");
        city.addItem("Montanan");
        city.addItem("New York");
        city.addItem("Oklahoma");

        jp.add(city);

        setTitle("JComboBox Demo");
        setVisible(true);
        setSize(300,200);
        add(jp);
    }

    public static void main(String[] args)
    {
        ComboBoxDemo cobj = new ComboBoxDemo();
    }

}
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the ComboBoxDemo Class

JButton

The following table lists the most commonly used constructors of the `JButton` class with their description.

Constructor	***Description***
`JButton()`	*Creates an instance without any text or icon.*
`JButton(String text)`	*Creates an instance with the specified text.*
`JButton(Icon icon)`	*Creates an instance with the specified icon.*

The Constructors of the JButton Class

The following table lists the most commonly used methods of the `JButton` class with their description.

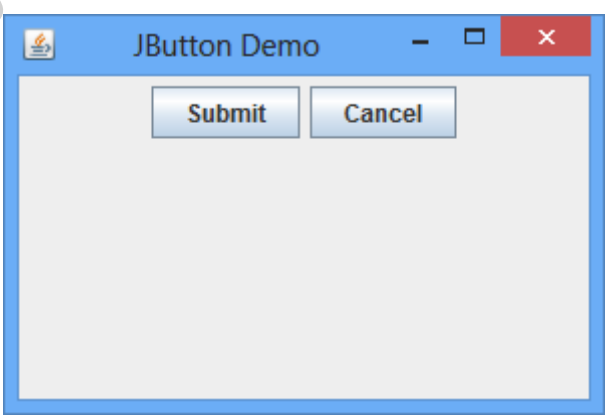
Method	***Description***
`void setText(String text)`	*Is used to define the text that will be displayed by the button.*
`void setSize(int width, int height)`	*Is used to resize the button with the specified width and height.*
`void setVisible(boolean b)`	*Is used to show or hide the button according to the passed parameter.*
`String getText()`	*Is used to retrieve the text of the button.*

The Methods of the JButton Class

Consider the following code to create `JButton`:

```
import javax.swing.JButton;
import javax.swing.JFrame;
import javax.swing.JPanel;

public class ButtonDemo extends JFrame
{
    JPanel jp;
    JButton submit, cancel;

    public ButtonDemo()
    {
        jp = new JPanel();

        submit = new JButton("Submit");


        cancel = new JButton("Cancel");

        jp.add(submit);
        jp.add(cancel);

        setTitle("JButton Demo");
        setVisible(true);
        setSize(300,200);
        add(jp);

    }

    public static void main(String[] args)
    {
        ButtonDemo bobj = new ButtonDemo();
    }

}
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the ButtonDemo Class

JOptionPane

The following table lists the most commonly used constructors of the `JOptionPane` class with their description.

Constructor	***Description***
`JOptionPane()`	*Creates an instance with a text message.*
`JOptionPane(Object message)`	*Creates an instance to display a message using the plain-message type and the default button, OK.*
`JOptionPane(Object message, int messageType)`	*Creates an instance to display a message with the specified message type, such as `ERROR_MESSAGE` or `QUESTION_MESSAGE`, and with the default button, OK.*

The Constructors of the JOptionPane Class

The following table lists the most commonly used methods of the `JOptionPane` class with their description.

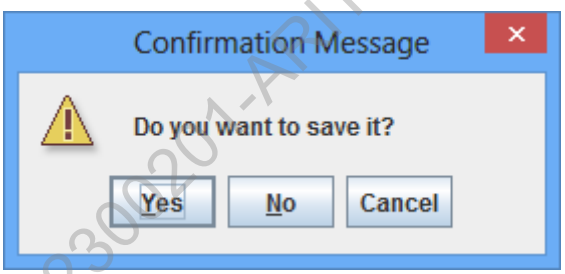
Method	***Description***
`static int showConfirmDialog(Component parentComponent, Object message, String title, int optionType, int messageType, Icon icon)`	*Is used to display a confirmation dialog box with the specified parent component, such as Frame, specified message, specified title, specified optionType, such as `YES_NO_OPTION` or `YES_NO_CANCEL`, specified messageType, such as `ERROR_MESSAGE` or `WARNING_MESSAGE`, and specified icon.*
`Static Object showInputDialog(Component parentComponent, Object message, String title, int optionType, int messageType, Icon icon, Object[] selectionValues, Object initialSelectionValue)`	*Is used to display a input dialog box with the specified parent component, such as a frame, specified message, specified title, specified optionType, such as `YES_NO_OPTION` or `YES_NO_CANCEL`, specified messageType, such as `ERROR_MESSAGE` or `WARNING_MESSAGE`, specified icon, specified array of possible selection values, and specified value that is used to initialize the input field.*
`static void showMessageDialog(Component parentComponent, Object message, String title, int messageType, Icon icon)`	*Is used to display a message dialog box with the specified parent component, such as a frame, specified message, specified title, specified messageType, such as `ERROR_MESSAGE` or `WARNING_MESSAGE`, and specified icon.*

The Methods of the JOptionPane Class

Consider the following code to create `JOptionPane`:

```
import javax.swing.JFrame;
import javax.swing.JOptionPane;

class OptionPaneDemo extends JFrame
{

        public OptionPaneDemo()
        {
            setVisible(true);
            setSize(100,100);
            JOptionPane.showConfirmDialog(this, "Do you want to save it?",
"Confirmation Message", JOptionPane.YES_NO_CANCEL_OPTION,
JOptionPane.WARNING_MESSAGE);
        }

        public static void main(String[] args)
        {
            OptionPaneDemo oobj = new OptionPaneDemo();
       }
}
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the OptionPaneDemo Class

Just a minute:

Which one of the following classes is the sub class of the `Window` class?

1. `JPanel`
2. `JFrame`
3. `JList`
4. `JTabbedPane`

Answer:

2. `JFrame`

Managing Layouts

Once you have created the UI components of an application, it is important to arrange them properly to enhance the look and feel of the application. To arrange the components in a container, you can use the various layout classes, such as `FlowLayout` and `BorderLayout`. These layouts use relative positioning to place the components on the container that means the components automatically adjust their position according to the frame size. The `setLayout()` method is used to set the layout of the containers. Java provides the various layouts.

Some of the layout manager classes are:

- `FlowLayout`
- `BorderLayout`
- `GridLayout`
- `GridBagLayout`
- `BoxLayout`
- `GroupLayout`

Using FlowLayout

`FlowLayout` places components in a sequence one after the other component in a row. By default, the components are aligned in the center and are placed from left to right and top to bottom. However, the orientation of the components can be changed by using the `setComponentOrientation()` method.

This method can accept the following values:

- `ComponentOrientation.LEFT_TO_RIGHT`
- `ComponentOrientation.RIGHT_TO_LEFT`

The `FlowLayout` class provides the various constructors that can be used to create an instance.

Some of the constructors are:

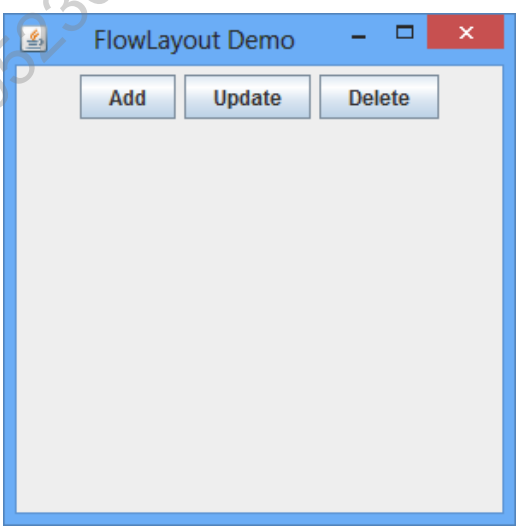
- `FlowLayout()`: Creates an instance with the centered alignment and with the default horizontal and vertical space of 5 pixels between the components.
- `FlowLayout(int align)`: Creates an instance with the specified alignment, such as `LEFT`, `RIGHT`, and `CENTER`, and the default horizontal and vertical space of `5` pixels between the components.
- `FlowLayout(int align, int hgap,int vgap)`: Creates an instance with the specified alignment and the specified horizontal and vertical space between the components.

For example, you want to add three buttons, add, update, and delete, in a row, in a sequence of one after the other.

For this, you can use the following code:

```
import java.awt.FlowLayout;
import javax.swing.JButton;
import javax.swing.JFrame;

public class FlowLayoutDemo extends JFrame
{
    JButton add, update, delete;

    public FlowLayoutDemo()
    {
        add = new JButton("Add");
        update = new JButton("Update");
        delete = new JButton("Delete");

        setVisible(true);
        setSize(300,300);
        setTitle("FlowLayout Demo");

        setLayout(new FlowLayout());
        add(add);
        add(update);
        add(delete);
    }

    public static void main(String[] args)
    {
        FlowLayoutDemo obj = new FlowLayoutDemo();
    }
}
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the FlowLayoutDemo Class

Using BorderLayout

`BorderLayout` divides the container into five regions: `NORTH`, `SOUTH`, `EAST`, `WEST`, and `CENTER`. Each region can contain only a single component. `BorderLayout` arranges and resizes the components to place them in the five regions. It is the default layout of the frame container. By default, the components are added in the `CENTER` region.

However, you can specify the region for the border layout using the following fields:

- `BorderLayout.NORTH`
- `BorderLayout.SOUTH`
- `BorderLayout.EAST`
- `BorderLayout.WEST`
- `BorderLayout.CENTER`

The `BorderLayout` class provides the various constructors that can be used to create an instance. Some of these constructors are:

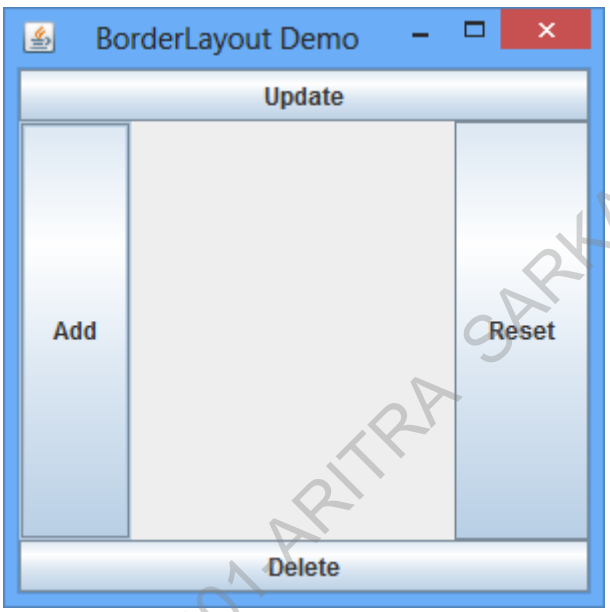
- `BorderLayout()`: Creates an instance with no space between the components.
- `BorderLayout(int hgap, int vgap)`: Creates an instance with the specified horizontal and vertical spaces between the components.

For example, you want to add four buttons, add, update, delete, and reset, in four different regions. For this, you can use the following code:

```
import java.awt.BorderLayout;
import javax.swing.JButton;
import javax.swing.JFrame;

public class BorderLayoutDemo extends JFrame
{
    JButton reset, add, update, delete;

    public BorderLayoutDemo()
    {
        reset = new JButton("Reset");
        add = new JButton("Add");
        update = new JButton("Update");
        delete = new JButton("Delete");


        setVisible(true);
        setSize(300,300);
        setTitle("BorderLayout Demo");

        setLayout(new BorderLayout());
        add(reset, BorderLayout.EAST);
        add(add, BorderLayout.WEST);
        add(update,BorderLayout.NORTH);
        add(delete, BorderLayout.SOUTH);
    }
```

```
    public static void main(String[] args)
    {
        BorderLayoutDemo obj = new BorderLayoutDemo();
    }
}
```

After executing the preceding code, the output is displayed, as shown in the following figure.



The Output of the BorderLayoutDemo Class

Exploring Java Event Model

In a GUI application, a user interacts with User Interface (UI) in various ways, such as by clicking a button, moving a mouse, entering text in a text field, and selecting an item from a list. Moreover, the interaction can also be generated by the application itself, such as when a timer expires, the printing process of a document completes, and some hardware or software failure occurs. The interaction with the application is incorporated in Java programs by using the event model.

The event model is based on two entities, source and receiver. The source initiates the interaction and the receiver processes the interaction generated by the source. In Java, events are handled by the classes and interfaces defined in the `java.awt.event` package.

Introducing Event Model

In Java programs, the event model contains the following three components that are responsible for handling the interaction between the source and the receiver:

- Event source
- Event listener
- Event handler

Event Source

An *event source* is an object that generates an event. The object registers some handler, which receives notifications about a specific type of event. For example, clicking of a button is an event that is fired by the button. In this example, the button is the source of the event and the button-click-event is the notification that is sent to the handler.

There are various components in the Swing toolkit, such as button, frame, and combo box, which act as an event source. These sources generate various events, such as a button generates an action event when the button is clicked, a frame generates the window event when the window is opened or closed, and a combo box generates the item event when an item is selected or deselected.

Event Listener

An *event listener* listens for a specific event and gets notified when the specific event occurs. An event listener registers with one or more event sources to receive notifications about specific types of events and to process the events. Once the listener is notified of a specific event, it calls the *event handler* and passes the information regarding the event. The information may contain the source that generated the event and the time when the event was generated.

Event Handler

An event handler is a method that is invoked by an event listener when the event is generated. In Java, event listeners are the interfaces and event handlers are the methods declared in the event listener interface that is implemented by the application.

Introducing Event Classes

Event classes represent the characteristics of all events, such as the source, time, and ID of the event. Whenever an event occurs, the related object of the event class is created. For example, when the mouse button is clicked, an object of the `MouseEvent` class is created. Some of the event classes provided by Java are:

- `ActionEvent`
- `KeyEvent`
- `MouseEvent`
- `FocusEvent`
- `ItemEvent`
- `WindowEvent`

The `EventObject` class, which is in the `java.util` package, is the superclass for all event classes. The class, `EventObject`, from which all event objects are derived, extends the `Object` class and implements the `Serializable` interface. The syntax of one of the constructors in the `EventObject` class is:

```
public EventObject(Object source)
```

In the preceding syntax, `source` is an object that generates an event. The `EventObject` class contains two methods, the `getSource()` method and the `toString()` method. The `getSource()` method returns the object on which an event has actually occurred. The `toString()` method returns the string representation of the object involved in the event.

ActionEvent

The action event is generated by components, such as a button, when an action is performed. For example, clicking of a button is an action event generated by the button. The following table lists the most commonly used methods of the `ActionEvent` class.

Method	***Description***
`String getActionCommand()`	*Returns the command string or the label of the event source. For example, clicking a button generates an action event and the `getActionCommand()` method returns the label of the button.*
`long getWhen()`	*Returns the timestamp when the event occurs.*
`Object getSource()`	*Returns the object that initiates the event.*
`int getModifiers()`	*Returns an integer value that indicates the modifiers keys, such as CTRL, ALT, and SHIFT, which are held down at the time of the event.*

The Methods of the ActionEvent Class

Note

You need to convert the long value to the `java.util.Date` class object to display the long value in the day, date, and time format.

MouseEvent

The mouse event is generated by a mouse with respect to the source component. These mouse events can have the following two categories:

- **Mouse events**: It contains the mouse events, such as mouse pressed, mouse clicked, and mouse entered.
- **Mouse motion events**: It contains the mouse motion events, such as mouse moved and mouse dragged.

The following table lists the most commonly used methods of the `MouseEvent` class.

Method	***Description***
`int getClickCount()`	*Returns the total count of the mouse clicks.*
`Point getPoint()`	*Returns the x and y coordinates of the mouse with respect to the source component.*
`int getX()`	*Returns the x coordinates of the mouse with respect to the source component.*
`int getY()`	*Returns the y coordinates of the mouse with respect to the source component.*

The Methods of the MouseEvent Class

KeyEvent

The key event is generated by a component when a key is pressed, released, or typed within the component. The following table lists the most commonly used methods of the `KeyEvent` class.

Method	***Description***
`int getKeyCode()`	*Returns the integer key code for the key.*
`static String getKeyText(int keyCode)`	*Returns the name of the key, such as Home, F1, and Caps Lock.*
`char getKeyChar()`	*Returns the character associated with the key.*

The Methods of the KeyEvent Class

FocusEvent

The focus event is generated by a component when it receives or loses focus. The focus events have the following levels:

- **Permanent**: It occurs when the focus directly moves from one component to other. For example, when you use the TAB key or the mouse to traverse from one component to other.
- **Temporary**: It occurs when the focus is temporarily lost for a component as an indirect result of another operation. For example, when you open a frame by clicking a button, the focus shifts temporarily from the button to the frame. When you close the frame, the focus shifts back from the frame to the button.

The following table lists the most commonly used methods of the `FocusEvent` class.

Method	***Description***
`boolean isTemporary()`	*Identifies whether the focus is changed permanently or temporarily.*
`component getOppositeComponent()`	*Returns the opposite component that is involved in focus or activation change. For example, if the focus gained event occurs, the opposite component, which lost focus, is returned; and if the focus lost event occurs, the opposite component, which gains focus, is returned.*

The Methods of the FocusEvent Class

ItemEvent

The item event is generated by components, such as radio button, and check box, when an item or the component is selected or deselected by the user. The following table lists the most commonly used methods of the `ItemEvent` class.

Method	***Description***
`Object getItem()`	*Returns the item affected by the event.*
`ItemSelectable getItemSelectable()`	*Returns the originator of the event.*
`int getStateChange()`	*Returns the changed state (selected or deselected).*

The Methods of the ItemEvent Class

WindowEvent

The window event is generated by window when it is opened, closed, activated, deactivated, or when focus is transferred into or out of the window.

The following table lists the most commonly used methods of the `WindowEvent` class.

Method	***Description***
`int getNewState()`	*Returns the new state of the window.*
`int getOldState()`	*Returns the previous state of the window.*
`Window getWindow()`	*Returns the originator of the event.*

The Methods of the WindowEvent Class

Introducing Event Listeners

An event listener provides the event handler methods that are used to handle events. For example, when a button is clicked, the `actionPerformed()` method of the `ActionListener` interface is responsible for handling the button-click event. Some of the event listener interfaces provided by Java are:

- `ActionListener`
- `KeyListener`
- `MouseListener`
- `MouseMotionListener`
- `FocusListener`
- `ItemListener`
- `WindowListener`

ActionListener

The `ActionListener` interface handles the action event. It is implemented by the class that processes the action events. The following table lists the method provided by the `ActionListener` interface to handle the specific events.

Method	***Description***
void actionPerformed(ActionEvent e)	*Is used to handle the event that occurs when an action is performed.*

The Method of the ActionListener Interface

KeyListener

The `KeyListener` interface handles the keyboard events generated by keystrokes. The class needs to implement the `KeyListener` interface that handles the keyboard events.

The following table lists the methods provided by the `KeyListener` interface to handle the specific events.

Method	***Description***
`void keyPressed(KeyEvent e)`	*Is used to handle the event that occurs when a key is pressed.*
`void keyReleased(KeyEvent e)`	*Is used to handle the event that occurs when a key is released.*
`void keyTyped(KeyEvent e)`	*Is used to handle the event that occurs when a key is typed.*

The Methods of the KeyListener Interface

MouseListener

The `MouseListener` interface handles the mouse events that occur when the mouse pointer is within the bounds of the component. The following table lists the methods provided by the `MouseListener` interface to handle the specific events.

Method	***Description***
`void mouseClicked(MouseEvent e)`	*Is used to handle the event that occurs when the mouse button is pressed and released.*
`void mouseEntered(MouseEvent e)`	*Is used to handle the event that occurs when the mouse enters a component.*
`void mouseExited(MouseEvent e)`	*Is used to handle the event that occurs when the mouse exits a component.*
`void mousePressed(MouseEvent e)`	*Is used to handle the event that occurs when the mouse button is pressed.*
`void mouseReleased(MouseEvent e)`	*Is used to handle the event that occurs when the mouse button is released.*

The Methods of the MouseListener Interface

MouseMotionListener

The `MouseMotionListener` interface handles the events that occur on the mouse movement with respect to the component.

The following table lists the methods provided by the `MouseMotionListener` interface to handle the specific events.

Method	***Description***
`void mouseDragged(MouseEvent e)`	*Is used to handle the event that occurs when a mouse button is pressed and then dragged.*
`void mouseMoved(MouseEvent e)`	*Is used to handle the event that occurs when a mouse cursor is moved.*

The Methods of the MouseMotionListener Interface

FocusListener

The `FocusListener` interface handles the events that occur when the component gains or loses the focus. The following table lists the methods provided by the `FocusListener` interface to handle the specific events.

Method	***Description***
`void focusGained(FocusEvent e)`	*Is used to handle the event that occurs when a component gains the focus.*
`void focusLost(FocusEvent e)`	*Is used to handle the event that occurs when a component loses the focus.*

The Methods of the FocusListener Interface

ItemListener

The `ItemListener` interface handles the events generated by the selectable component, such as combo box and radio button. The following table lists the method provided by the `ItemListener` interface to handle the specific events.

Method	***Description***
`void itemStateChanged(ItemEvent e)`	*Is used to handle the event that occurs when a component is selected or deselected.*

The Method of the ItemListener Interface

WindowListener

The `WindowListener` interface handles the events generated by the window. The following table lists the methods provided by the `WindowListener` interface to handle specific events.

Method	***Description***
`void windowActivated(WindowEvent e)`	*Is used to handle the event that occurs when a window is active.*
`void windowClosed(WindowEvent e)`	*Is used to handle the event that occurs when a window is closed as a result of calling the dispose operation on the window.*
`void windowClosing(WindowEvent e)`	*Is used to handle the event that occurs when a window is closed from the window's system menu or by clicking the close button of the window.*
`void windowDeactivated(WindowEvent e)`	*Is used to handle the event that occurs when a window is no longer active.*
`void windowOpened(WindowEvent e)`	*Is used to handle the event that occurs when a window is visible for the first time.*

The Methods of the WindowListener Interface

Note

The window's system menu is the menu that is accessible by clicking the upper left icon on the window.

Implementing Events

In event handling, the source generates an event and notifies one or more event listeners. It is necessary to register the listener with a source in order to get notified about the occurrence of a particular event. Once the event listener is notified, it processes the event. In order to achieve event handling in a Java program, you need to implement an event handler and associate the event handler with the source.

Implementing Event Handlers

In a GUI application, the initiated actions must be handled by the application. In order to handle the users' action, you need to implement the event handler. For this, you need to override the methods of the listener interfaces or the methods of the adapter classes. For example, you want to display, Welcome to Java, on a frame on the click of a button. For this, you need to override the `actionPerformed()` method of the `ActionListener` interface, as shown in the following code:

```
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;
import javax.swing.JButton;
import javax.swing.JFrame;
import javax.swing.JLabel;
import javax.swing.JPanel;

public class ActionEventDemo extends JFrame implements ActionListener
{

    JButton click;
    JPanel panel;
    JLabel message;

    public ActionEventDemo()
    {
        super("Action Event Demo");
        click = new JButton("Click");
        panel = new JPanel();
        message = new JLabel();

        add(panel);
        panel.add(click);
        panel.add(message);

        setSize(300, 300);
        setVisible(true);

        /* Some code to be added */
    }

    public void actionPerformed(ActionEvent e)
    {
        message.setText("Welcome to Event Handling in Java");
    }
```

```
    public static void main(String[] args)
    {
        ActionEventDemo obj = new ActionEventDemo();
    }
}
```

In the preceding code, the `ActionEventDemo` class implements the `ActionListener` interface and overrides the `actionPerformed()` method to handle the event generated by the button, `click`.

Let's consider another example where you want to display the current position of the mouse cursor within the frame. For this, you can override the `mouseMoved()` and `mouseDragged()` methods of the `MouseMotionListener` interface, as shown in the following code:

```
import java.awt.FlowLayout;
import java.awt.event.MouseEvent;
import java.awt.event.MouseMotionListener;
import javax.swing.JFrame;
import javax.swing.JLabel;

public class MouseMotionDemo extends JFrame implements MouseMotionListener
{

    int x, y;
    JLabel position;

    public MouseMotionDemo()
    {
        super("Mouse Motion Event Demo");
        position = new JLabel();

        setLayout(new FlowLayout());

        add(position);

        setSize(320, 300);
        setVisible(true);

        /* Some code to be added */
    }

    public void mouseMoved(MouseEvent me)
    {
        x = me.getX();
        y = me.getY();
        position.setText("Mouse cursor is at " + x + " " + y);
    }

    public void mouseDragged(MouseEvent me)
    {
        x = me.getX();
        y = me.getY();
        position.setText("Mouse is dragged at " + x + " " + y);
    }
```

```
    public static void main(String[] args)
    {
        MouseMotionDemo obj = new MouseMotionDemo();
    }
}
```

In the preceding code, the `MouseMotionDemo` class implements the `MouseMotionListener` interface and overrides the `mouseMoved()` and `mouseDragged()` methods, which handle the mouse events.

Consider another example where you want to show a confirmation dialog box when a user tries to close a frame. For this, you need to override the `windowClosing()` method of the `WindowListener` interface. However, if we implement the listener, you need to override all the methods. Therefore, instead of using the listener, you can use the `WindowAdapter` class, as shown in the following code:

```
import java.awt.event.WindowAdapter;
import java.awt.event.WindowEvent;
import javax.swing.JFrame;
import javax.swing.JOptionPane;
import javax.swing.WindowConstants;

public class WindowDemo extends WindowAdapter
{

    JFrame jf;

    public WindowDemo()
    {
        jf = new JFrame("Window Event Demo");
        jf.setSize(300, 300);
        jf.setVisible(true);
        jf.setDefaultCloseOperation(WindowConstants.DO_NOTHING_ON_CLOSE);
        /* Some code to be added */

    }

    public void windowClosing(WindowEvent e)
    {
        int n = JOptionPane.showConfirmDialog(jf, "Do you want to close this
window?", "Confirmation", JOptionPane.YES_NO_CANCEL_OPTION,
JOptionPane.QUESTION_MESSAGE);
        if (n == JOptionPane.YES_OPTION)
        {

            jf.dispose();

        }

    }

    public static void main(String[] args)
    {
        WindowDemo obj = new WindowDemo();
    }
}
```

In the preceding code, the `WindowDemo` class extends the `WindowAdapter` class and overrides the `windowClosing()` method, which handle the mouse events.

Just a minute:

Which one of the following interfaces contains the method that helps to implement the functionality to locate the mouse cursor within the frame?

1. `MouseListener`
2. `MouseMotionListener`
3. `WindowListener`
4. `ActionListener`

Answer:

2. `MouseMotionListener`

Just a minute:

Which one of the following code snippets registers the `ActionListener` interface to the implementing class for handling the action events?

1. `addActionPerformed(this)`
2. `addActionListener(this)`
3. `addPerformedAction(this)`
4. `addListnerAction(this)`

Answer:

2. `addActionListener(this)`

Practice Questions

1. Which one of the following methods is used to set the layout of a container?
   a. `setLayout()`
   b. `startLayout()`
   c. `initLayout()`
   d. `layoutContainer()`

2. Which one of the following components allows adding multiple lines of text?
   a. `JTextField`
   b. `JTextArea`
   c. `JOptionPane`
   d. `JDialog`

3. Which one of the following components is used to create a set of components that are grouped together in which only one component can be selected?
   a. `JCheckBox`
   b. `JButton`
   c. `JRadioButton`
   d. `JFrame`

4. State whether the following statement is true or false.
   The `JLabel` class does not allow you to add an icon on the label.

5. Which one of the following components of the event model listens for a specific event?
   a. Event source
   b. Event handler
   c. Event class
   d. Event object

6. Which one of the following event classes contains the `getX()` and `getY()` methods?
   a. `MouseEvent`
   b. `KeyEvent`
   c. `ActionEvent`
   d. `FocusEvent`

7. Which one of the following event listeners contains the `mouseMoved()` method?
   a. `MouseListener`
   b. `FocusListener`
   c. `MouseMotionListener`
   d. `ItemListener`

8. Which one of the following event listeners handles the event generated by selecting the radio button?
   a. `ItemListener`
   b. `WindowListener`
   c. `ActionListener`
   d. `MouseListener`

Summary

In this chapter, you learned that:

- In a CUI application, a user needs to remember all the commands to work with the application.
- The GUI provides a graphical way of interacting with the application.
- Java provides the various UI components, such as `JFrame`, `JPanel`, `JButton`, and `JLabel`, of the `javax.swing` package.
- The most commonly used containers and components are:
  - `JFrame`
  - `JDialog`
  - `JPanel`
  - `JTabbedPane`
  - `JMenuBar`
  - `JMenu`
  - `JMenuItem`
  - `JLabel`
  - `JTextField`
  - `JTextArea`
  - `JCheckBox`
  - `JRadioButton`
  - `JList`
  - `JComboBox`
  - `JButton`
  - `JOptionPane`
- You need to import the classes and the interfaces available in the `javax.swing` package to create the UI of the applications.
- To arrange the components in a container, you can use the various layouts, such as `FlowLayout` and `BorderLayout`.
- The `setLayout()` method is used to set the layout of the containers.
- You can use the `setLayout()` method of the container and pass `null` as an argument to create a container without a layout manager.
- The interaction with the application is incorporated in Java programs by using the event model.
- The event model is based on two entities, source and receiver.
- In Java, events are handled by the classes and interfaces defined in the `java.awt.event` package.
- In Java programs, the event model contains the following three components that are responsible for handling the interaction between the source and the receiver:
  - Event source
  - Event listener
  - Event handler

- An event source is an object that generates an event.
- An event listener listens for a specific event and gets notified when the specific event occurs.
- An event handler is a method that is invoked by an event listener when the event is generated.
- Event classes represent the characteristics of all events. Some of the event classes provided by Java are:
  - `ActionEvent`
  - `KeyEvent`
  - `MouseEvent`
  - `FocusEvent`
  - `ItemEvent`
  - `WindowEvent`
- The `EventObject` class, which is in the `java.util` package, is the superclass for all event classes.
- The action event is generated by components, such as a button, when an action is performed.
- The mouse event is generated by a mouse with respect to the source component.
- The key event is generated by a component when a key is pressed, released, or typed within the component.
- The focus event is generated by a component when it receives or loses focus.
- The item event is generated by components, such as radio button, and check box, when an item or the component is selected or deselected by the user.
- The window event is generated by window when it is opened, closed, activated, deactivated, or when focus is transferred into or out of the window.
- Some of the event listener interfaces provided by Java are:
  - `ActionListener`
  - `KeyListener`
  - `MouseListener`
  - `MouseMotionListener`
  - `FocusListener`
  - `ItemListener`
  - `WindowListener`
- The `ActionListener` interface handles the action event.
- The `KeyListener` interface handles the keyboard events generated by keystrokes.
- The `MouseListener` interface handles the mouse events that occur when the mouse pointer is within the bounds of the component.
- The `MouseMotionListener` interface handles the events that occur on the mouse movement with respect to the component.
- The `FocusListener` interface handles the events that occur when the component gains or loses the focus.
- The `ItemListener` interface handles the events generated by the selectable component, such as combo box and radio button.
- The `WindowListener` interface handles the events generated by the window.

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Implementing Inner Classes

CHAPTER 2

At times, you need to develop a helper class that should provide a very specific functionality to another class in the program. However, at the same time, you also want to ensure that the helper class is not accessible to other class. This can be achieved by defining the helper class inside the class that uses the functionality. A class defined within another class is called an inner class. The inner class increases encapsulation. In addition, it makes the code readable and maintainable.

There are times when you need to convert the data from one type into another. For this, Java supports type casting.

This chapter focuses on creating inner classes.

Objectives

In this chapter, you will learn to:

- Create inner classes

Creating Inner Class

Consider a scenario where you are developing a Java application to process credit card payments for clients, such as retail stores. In this application, you have created a `CreditCard` class that models the credit card used for payment by a client. The `CreditCard` class defines private fields for sensitive information, such as the credit card number, expiry date, and CVV number. You need to create a `CreditCardValidator` class that contains the business logic to validate a credit card using an object of the `CreditCard` class. However, you cannot create a separate `CreditCardValidator` class as it will not be able to access the private fields of the `CreditCard` class required for performing the validation. In such a scenario, you can use an inner class. *Inner classes* are the classes defined inside another class. Java provides the following four types of inner classes:

- Regular inner class
- Static inner class
- Method-local inner class
- Anonymous inner class

Regular Inner Class

Consider the scenario of a Bill Desk application used in the departmental store. This application requires login credentials to login. Therefore, you need to create a class named `Login`, which will have the username and password fields. As these details should not be accessible to other classes, you need to declare the username and password as private fields. However, the login credentials provided by the user need to be validated. Therefore, you need to define a class named `ValidateCredentials` to implement the validation logic. However, if this class is declared as an outer class, you cannot access the private fields. Therefore, to implement the preceding functionality, you need to create a regular inner class.

A *regular inner class* is a class whose definition appears inside the definition of another class. The regular inner class is similar to a member of an outer class. Therefore, the regular inner class shares all the features of a member of a class. The following code snippet demonstrates an example for the regular inner class:

```
public class Login
{
    private String username;
    private String password;
    class ValidateCredentials
    {
          public void validate()
          {
             // the private fields username and password are accessible here
          }
    }
}
```

In the preceding code snippet, a class, `ValidateCredential`, is created inside the class, `Login`. The `validate()` method of `ValidateCredential` can access all the members of the `Login` class. Therefore, the private fields, `username` and `password`, are accessible to the `validate()` method.

In order to instantiate an inner class outside the outer class, you first need to get the reference of the outer class object and create an object of the inner class, as shown in the following code snippet:

```
Login obj=new Login ();
Login.ValidateCredentials cobj= obj.new ValidateCredentials ();
```

Static Inner Class

Consider a scenario of the Payment Gateway application. In this application, you need to implement the logic to validate various details, such as credit card, debit card, and net banking account login details. In order to meet the preceding requirement, you can use a regular inner class. However, to access a regular inner class outside the class, you need to instantiate the outer class. Thereafter, by using the outer class object, you need to instantiate the inner class. This means that for each request for a validation, two objects, one for the outer class and another for the inner class, will be created in the heap.

Consider an example of an enterprise application where a large number of users are making numerous validation requests. Therefore, the amount of objects that will get assigned to the heap will increase. This will adversely affect the performance of the application.

Therefore, to address the preceding challenge, you can create a static inner class. As a result, you will be able to minimize the amount of objects, which are required to access the inner class functions. This is because in order to access a static inner class, you do not need its enclosing outer class object.

Static inner classes are inner classes marked with the static modifier. The following code snippet demonstrates an example for static inner classes:

```
class PaymentDetails
{
    private static String fieldToValidate;
    static class ValidateCreditCards
    {
        void validate()
        {
           /* code be added */
        }
    }
    static class ValidateDebitCards
    {
        void validate()
        {
           /* code be added */
        }
    }
    static class ValidateNetBankingAccount
    {
        void validate()
        {
           /* code be added */
        }
    }
}
```

In the preceding code snippet, `ValidateCreditCards`, `ValidateDebitCards` and `ValidateNetBankingAccount` are static inner classes defined inside the `PaymentDetails` class.

You need to use the following code snippet to instantiate the `ValidateNetBankingAccount` static inner class outside the `PaymentDetails` class:

```
PaymentDetails.ValidateNetBankingAccount validator=new
PaymentDetails.ValidateNetBankingAccount();
```

Note

A static inner class cannot directly access the member variables of the outer class. Therefore, to access the member variables, you need to create the instance of the outer class inside the inner class.

Method-local Inner Class

A *method-local inner* class is defined inside the method of the enclosing class. Because the class is defined inside a method, it needs to be instantiated within the same method.

Consider the following code snippet of the method-local inner class:

```
public class MethodLocalInner
{
    private String x = "MyOuterClass";
    void display()
    {
        final String z = "local variable";
        System.out.println(x);
        class Inner
        {
            public void print()
            {
                System.out.println("Outer x: " + x);
                System.out.println("Local variable z: " + z);
            }
        }
        Inner obj = new Inner();
        obj.print();
    }
    public static void main(String args[])
    {
        MethodLocalInner m = new MethodLocalInners();
        m.display();
    }
}
```

In the preceding code snippet, a `MethoLocalInner` class with a method named `display()` is created. In the `display()` method, a class named `Inner` is created with a method named `print()`.

Anonymous Inner Class

Consider a scenario where you need to develop a gaming application by using the Swing components. In this application, you need to design a startup screen interface with a start button. In addition, you want to implement the functionality wherein the game should begin when the start button is clicked. To implement this functionality, you need to override the `actionPerformed()` method of the `ActionListener` interface, as shown in the following code snippet:

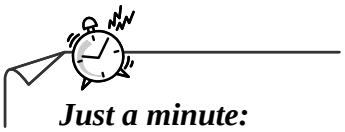
```
class StartUpAction implements ActionListener
{
    public void actionPerformed(ActionEvent e)
    {
        /* code to be added here */
    }
}
public class StartUpScreen
{
   JFrame jf;
   JButton start;
   StartUpScreen()
   {
       jf=new JFrame("Startup Screen");
       start=new JButton("Start");
       jf.setLayout(new FlowLayout());
       jf.add(start);
       jf.setSize(300,300);
       jf.setVisible(true);
       start.addActionListener(new StartUpAction());
   }
}
```

The `StartUpAction` class is accessible to other classes in the application. However, the functionality defined in the `StartUpAction` class is not required by other classes in the application. Therefore, you need not define an outer class. In addition, the instance of this class is used only once. Therefore, with the help of an anonymous inner class, the functionality provided by the `StartUpAction` class can be implemented. An *anonymous inner class* has no name, and it is either a subclass of a class or an implementer of an interface. In case of the anonymous class, a curly brace is followed by the semicolon.

Consider the following code snippet to implement an anonymous inner class:

```
start.addActionListener(new ActionListener()
{
            public void actionPerformed(ActionEvent e)
            {
                 /* code to be added here */
            }
});
```

In the preceding code snippet, an anonymous inner class of the type, `ActionListener`, is created and the `actionPerformed()` method is overridden.



Just a minute:

Which one of the following inner classes can be defined without the name of the class?

1. *Regular inner class*
2. *Static inner class*
3. *Method-local inner class*
4. *Anonymous inner class*

Answer:

4. *Anonymous inner class*

Activity 2.1: Creating Inner Classes

Practice Questions

1. Which one of the following inner classes is defined inside the method of the enclosing class?
   a. Regular inner class
   b. Static inner class
   c. Method-local inner class

2. Which one of the following options correctly denotes an anonymous inner class?
   a. It is defined inside the method of the enclosing class.
   b. It is marked with a static modifier.
   c. It is similar to the member of the outer class.
   d. It does not have a name and is either a subclass of a class or an implementer of an interface.

3. State whether the following statement is true or false.
   Method-local inner class is defined inside the method of the enclosing class.

Summary

In this chapter, you learned that:

- A class defined within another class is called an inner class.
- Java provides the following four types of inner classes:
  - Regular inner class
  - Static inner class
  - Method-local inner class
  - Anonymous inner class
- A regular inner class is a class whose definition appears inside the definition of another class. The regular inner class is similar to a member of an outer class.
- Static inner classes are inner classes marked with the static modifier.
- A method-local inner class is defined inside the method of the enclosing class. Because the class is defined inside a method, it needs to be instantiated within the same method.

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Working with Localization

CHAPTER 3

At times, you want to develop applications that can be used worldwide. These applications should be able to display various pieces of information, such as text, currency, and date, according to the region where they are deployed. To meet this requirement, Java supports localization.

In this chapter, you will learn about implementing localization.

Objectives

In this chapter, you will learn to:

- Implement localization

Implementing Localization

Consider a scenario where you want to develop a hotel management application that can be used worldwide. You want that the text in the application should be displayed according to the region. For example, if the application is used in France, the text should be displayed in French and the currency should be displayed in Euros. To develop such applications, you need to implement localization, which is a process of customizing the application to a specific locale and culture. Localization can be implemented on different types of data, such as date, currency, and text. To localize different types of data, it is necessary to determine the language and country. To determine the language, Java provides a predefined set of language codes, such as `zh` for Chinese and `en` for English. In addition, it provides a predefined set of country codes, such as `AU` for Australia and `CN` for China. Further, to work with localization, the `Locale` class of the `java.util` package is used. The instance of the `Locale` class can be created, as shown in the following code snippet:

```
Locale l=new Locale("de","DE");
```

In the preceding code snippet, `de` specifies the language code and `DE` specifies the country code.

Localizing Date

To localize the date, you need to use the various date formats. To determine the date format according to the locale, you can use the `java.text.DateFormat` class. To display the date in German, the following code is used:

```
import java.text.DateFormat;
import java.util.*;
public class DateDemo {
    public static void main(String args[]){
        DateFormat df = DateFormat.getDateInstance(DateFormat.LONG, new
Locale("de","DE"));
        String date = df.format(new Date());
        System.out.println(date);
    }
}
```

The preceding code generates the following output:

```
4. Juni 2013
```

Note

The preceding output may vary based on the current system's date.

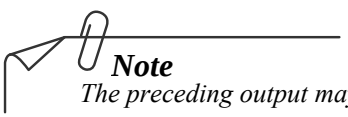
In the preceding code, `DateFormat.getDateInstance` is used to specify a formatting style for the German locale. `DateFormat.Long` specifies the description of the date according to the locale. The `String date = df.format(new Date());` statement formats the current date into the date string.

Similarly, to display the time in German, the following code is used:

```
import java.text.*;
import java.util.*;
public class TimeDemo {
    public static void main(String args[]){
        DateFormat df = DateFormat.getTimeInstance(DateFormat.LONG, new
Locale("de","DE"));
        String time = df.format(new Date());
        System.out.println(time);
    }
}
```

The preceding code generates the following output:

```
13:36:28 IST
```



Note

The preceding output may vary based on the current system's time.

In the preceding code, the `getTimeInstance()` method is used to specify a formatting style for the German locale. `DateFormat.Long` specifies the description of the date according to the locale. The `String time = df.format(new Date());` statement formats the current time into the string format.

Localizing Currency

To localize the currency, you need to use various currency formats. To determine the currency format according to the locale, you can use the `java.text.NumberFormat` class. To display the currency in German, the following code is used:

```
import java.text.*;
import java.util.*;
public class CurrencyDemo {
    public static void main(String args[]){
        NumberFormat nft = NumberFormat.getCurrencyInstance(new
Locale("de","DE"));
        String formatted = nft.format(1000000);
        System.out.println(formatted);
    }
}
```

The preceding code generates the following output:

```
1.000.000,00 €
```

In the preceding code, `NumberFormat.getCurrencyinstance` returns a currency format for the locale. The `String formatted = nft.format(1000000);` statement formats the currency into a string.

Localizing Text

To localize text, you need to use the resource bundles. A resource bundle is a property file that contains the locale specific data. To work with data stored in a resource bundle, you need to use the `ResourceBundle` class. `ResourceBundle` is a class that encapsulates a set of resources.

To access a particular resource, you need to obtain a reference of the `ResourceBundle` class and call its `getObject()` method.

To have a locale-specific object, a program needs to load the `ResourceBundle` object by using the `getBundle` method, as shown in the following code snippet:

```
ResourceBundle myResourceBundle = ResourceBundle.getBundle("MessagesBundle");
```

In the preceding code snippet, a `MessagesBundle` resource bundle has been loaded that contains the localized resource. When a the `getBundle()` method is called, the `ResourceBundle` tries to load a resource file with a variation of the name that was specified. It searches the resource bundle with the explicitly specified locale values appended to the name. It then searches the resource bundle with the default Locale's values.

For example, if the default Locale is `Locale.US`, then `getBundle()` will load the resource bundle file in the US locale.

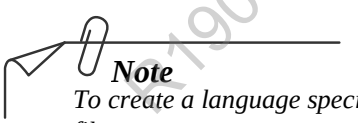
Consider a scenario where you need to develop a Java application that displays the message, Welcome, in German or Chinese. For this, you need to create the German and Chinese resource bundles.

You can create the German resource bundle file, such as `MessageBundle_de.properties`, and add the following code snippet inside the file to localize the message, Welcome, in German:

```
message=willkommen
```

You can create the Chinese resource bundle file, such as `MessageBundle_zn.properties`, and add the following code snippet inside the file to localize the message, Welcome, in Chinese:

```
message=歡迎
```



Note

To create a language specific resource bundle file, you need to specify the properties filename as `<resourcebundle name>_<language code>.properties`.

The following code demonstrates how the text is localized:

```
import java.util.Locale;
import java.util.ResourceBundle;
public class TestLocale {
    public static void main(String args[]){
        Locale l1=new Locale("de","DE");
        ResourceBundle rb1 = ResourceBundle.getBundle("MessageBundle",l1);
        System.out.println(rb1.getString("message"));
        Locale l2=new Locale("zn","ZN");
        ResourceBundle rb2 = ResourceBundle.getBundle("MessageBundle",l2);
        System.out.println(rb2.getString("message"));
    }

}
```

In the preceding code, the `getBundle()` method is used to load the `ResourceBundle` class when the program needs a locale-specific object. To retrieve an object from the resource bundle, the `getString()` method is used.

Just a minute:

Which one of the following statements denotes the correct way to create an instance of the `Locale` class?

1. `Locale l=new Locale("de", "DE");`
2. `Locale l=new Locale("DE", "de");`
3. `Locale l=new Locale('de', 'DE');`
4. `Locale l=new Locale('DE', 'de');`

Answer:

1. `Locale l=new Locale("de", "DE");`

Activity 3.1: Implementing Localization

Practice Questions

1. State whether the following statement is true or false.
   Localization is the process of customizing the application to a specific locale and culture.

2. Identify the correct option by using which the match succeeds if the given input string starts with any character between a and z, except b, c, and d.
   a. `[a-z&&[abc]]`
   b. `[b-z&&[^bcd]]`
   c. `[a-z&&[^n-p]]`
   d. `[abc]`

3. Identify the correct option that is used to match the pattern with the longest possible string.
   a. Greedy
   b. Reluctant
   c. Possessive

Summary

In this chapter, you learned that:

- Localization is a process of customizing the application to a specific locale and culture.
- Localization can be implemented on different types of data, such as date, currency, and text.
- To localize different types of data, it is necessary to determine the language and country.
- To determine the language, Java provides a predefined set of language codes, such as `zh` for Chinese and `en` for English.
- To work with localization, the `Locale` class of the `java.util` package is used.
- To localize the date, you need to use the various date formats. To determine the date format according to the locale, you can use the `java.text.DateFormat` class.
- To localize the currency, you need to use various currency formats. To determine the currency format according to the locale, you can use the `java.text.NumberFormat` class.
- To localize text, you need to use the resource bundles.
- A resource bundle is a property file that contains the locale specific data. To work with data stored in a resource bundle, you need to use the `ResourceBundle` class.
- To have a locale-specific object, a program needs to load the `ResourceBundle` object by using the `getBundle()` method.

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Working with Generics

CHAPTER 4

At times, you need to create interfaces, classes, and methods that may work with different types of data. For this, you need to write a robust and type-safe code, which is a tedious and error-prone task. To overcome the overhead of writing the type-safe code, Java provides the *generics* feature. Generics allow you to create generalized interfaces, classes, and methods.

This chapter focuses on the creation of the user-defined generic classes and methods and implementation of type-safety.

Objectives

In this chapter, you will learn to:

- Create user-defined generic classes and methods
- Implement type-safety

Creating User-defined Generic Classes and Methods

Consider a scenario where you need to develop a class with a method, which can return various objects, such as `Integer`, `String`, and `Double`. To implement the functionality, you need to create generic classes and methods. Generics mean parameterized types that enable you to write the code that can work with many types of object. In addition, it allows you to provide the enhanced functionality to classes and methods by making them generalized. The generic classes and methods are created so that the references and methods can accept any type of object.

Creating Generic Classes

Generics enable you to generalize classes. This means that a reference variable, an argument of a method, and a return type can be of any type. In the declaration of a generic class, the name of the class is followed by a *type parameter* section. The type parameter section is represented by angular brackets, `< >`, that can have one or more types of parameters separated by commas. The following syntax is used to create generic classes:

```
class [ClassName]<T>
{

}
```

You can create a generic class by using the following code snippet:

```
class GenericClassDemo<T>
{

}
```

Consider an example where you want to create a generic class to set and get the `Integer` and `String` values. For this, you can use the following code:

```
public class GenericClassDemo<T>
{
    private T t;

    public void setValue(T t)
    {
        this.t = t;
    }

    public T getValue()
    {
        return t;
    }

    public static void main(String[] args)
    {
        GenericClassDemo<Integer> iobj = new GenericClassDemo<Integer>();
```

```
            iobj.setValue(10);
            System.out.println(iobj.getValue());

            GenericClassDemo<String> sobj = new GenericClassDemo<String>();
            sobj.setValue("Ten");
            System.out.println(sobj.getValue());
        }
    }
```

Once the preceding code is executed, the following output is displayed:

```
10
Ten
```

In the preceding code, the `GenericClassDemo` class is created with two methods, `setValue()` and `getValue()`. `T` represents the type of data, which can accept any object, such as `Integer` and `String`. The `T` parameter in the preceding code is used as a reference type, return type, and method argument.

Creating a Generic Method

In the generic class, a method can use the type parameter of the class, which automatically makes the method generic. Consider the following code of the generic method inside the generic class:

```
public class GenericClassDemo<T>
{
    private T t;

    public void setValue(T t)
    {
        this.t = t;
    }

    public T getValue()
    {
        return t;
    }
}
```

In the preceding code, the `setValue()` and `getValue()` methods are using the class's type parameter.

However, you can declare a generic method, which contains its own one or more type parameters. The declaration of a generic method contains the type parameter that is represented by angular brackets, `< >`. The following syntax is used to create a generic method:

```
public <Type Parameter> [Return Type] [MethodName](Argument list…)
{
}
```

You can create a generic method, as shown in the following code snippet:

```
public <T> T showValue(T val)
{
}
```

The type parameter section can have one or more type of parameters separated by commas. Further, it is also possible to create a generic method inside a non generic class.

Consider the following code of the generic method inside the non generic class:

```
public class GenericMethodDemo
{
    public <M> M display(M val)
    {
        return val;
    }

    public static void main(String[] args)
    {
        GenericMethodDemo obj = new GenericMethodDemo();

        System.out.println("The generic method is called with String value: "
+ obj.display("Test"));
        System.out.println("The generic method is called with Double value: "
+ obj.display(7.5));
        System.out.println("The generic method is called with Boolean value:
" + obj.display(true));
        System.out.println("The generic method is called with Integer value:
" + obj.display(10));

    }
}
```

Once the preceding code is executed, the following output is displayed:

```
The generic method is called with String value: Test
The generic method is called with Double value: 7.5
The generic method is called with Boolean value: true
The generic method is called with Integer value: 10
```

In the preceding code, the `GenericMethodDemo` class contains the `display()` method that is used to display the values. In addition, inside the `main()` method, the display method is called four times with four different types of values.

Implementing Type-safety

Consider an example where you want to create an object of a generic class. To create the object, you need to invoke the constructor of a generic class with the required type of parameters, such as `Integer` or `String`, which increases the length of the code. However, to reduce the coding, Java provides the flexibility to leave the type parameters empty as long as the compiler can guess or judge the type of the argument from the context. In addition, Java provides wildcards that allow you to achieve inheritance in a type parameter.

Using a Generic Type Inference

You have learned how to create generic classes and methods. In order to use those classes or methods, you need to understand how Java infers the arguments that are provided as the type parameters. While using a generic type, you must provide the type argument for every type parameter declared for the generic type. The type argument list is a comma-separated list that is delimited by angular brackets and follows the type name. For example, consider the following code of a generic type with two type arguments:

```
class Pair<X, Y>
{

    private X first;
    private Y second;

    public Pair(X a1, Y a2)
    {
        first = a1;
        second = a2;
    }

    public X getFirst()
    {
        return first;
    }

    public Y getSecond() {
        return second;
    }

    public static void main(String[] args)
    {
        Pair<String, Integer> obj1 = new Pair<String, Integer>("Test", 1);
        System.out.println("String is " + obj1.getFirst());
        System.out.println("Integer is " + obj1.getSecond());

        Pair<Integer, String> obj2 = new Pair<Integer, String>(2, "Demo");
        System.out.println("Integer is " + obj2.getFirst());
        System.out.println("String is " + obj2.getSecond());

    }
}
```

Once the preceding code is executed, the following output is displayed:

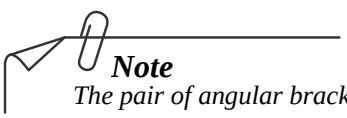
```
String is Test
Integer is 1
Integer is 2
String is Demo
```

In the preceding code, the `Pair` class contains two methods, `getFirst()` and `getSecond()`, which return the value of the `first` and `second` variables. In the `main()` method, two objects have been created that are of the `<String, Integer>` and `<Integer, String>` types.

Java provides a new feature, *type inference*, which enables you to invoke the constructor of a generic class with an empty set of type parameters, <>. The empty set of type parameters can be used as long as the compiler can infer the type arguments from the context.

Consider the preceding example in which you can use the empty set of type parameters while creating the objects of the `Pair` class, as shown in the following code snippet:

```
Pair<String, Integer> obj1 = new Pair<>("Test", 1);

Pair<Integer, String> obj2 = new Pair<>(2, "Demo");
```



Note

The pair of angular brackets, <>, is informally called the diamond operator.

Using Wildcards

Generics follow a simple rule of declaration, which says the type of reference variable declaration must match the type passed to the actual object. This means that in generics, a subclass cannot be passed as a subtype of a superclass, as shown in the following code snippet:

```
WildCardDemo<Number> obj = new WildCardDemo<Integer>();
```

Generics only allow the following type of declaration:

```
WildCardDemo<Integer> obj = new WildCardDemo<Integer>();
```

Or

```
WildCardDemo<Number> obj = new WildCardDemo<Number>();
```

However, Java provides wildcard arguments to pass a subclass as a subtype of a superclass in generics. The wildcard arguments are the special constructs that are used as a type argument in a generic type instance. There are various types of wildcards.

The following table lists the most commonly used wildcard arguments.

Wildcard	*Description*
`? extends`	*It specifies that the type can be anything that extends from the class specified after the* `extends` *keyword. It is a bounded wildcard.*
`? super`	*It specifies that the type can be anything that is the base class of the class specified after the* `super` *keyword. It is a bounded wildcard.*
`?`	*It specifies that the type can be anything. It doesn't need to be a subtype or super type of any class. It is an unbounded wildcard.*

The Wildcard Arguments

Note

A bounded wildcard is used to bound any type of object by using the keywords: `extends`*,* `implements`*, and* `super`*. An unbounded wildcard does not bind any type of object and does not associate with any keyword.*

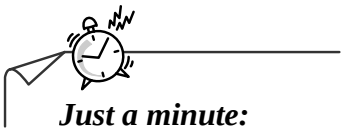
Consider an example where you want to compare the values of two objects. However, you want to compare only the numeric objects. For this, you can use the following code:

```
public class WildCardDemo<T> {

    private T t;

    public void setValue(T t) {
        this.t = t;
    }

    public T getValue() {
        return t;
    }
    public boolean compare(WildCardDemo<? extends Number> wcd)
    {
        if(t == wcd.t)
        {
            return true;

        }
        else
        {
            return false;
        }

    }
```

```
    public static void main(String[] args)
    {
        WildCardDemo<Integer> obj1 = new WildCardDemo<Integer>();
        obj1.setValue(10);

        WildCardDemo<String> obj2 = new WildCardDemo<String>();
        obj2.setValue("Test");

        System.out.println("Value of first object: " +obj1.getValue());
        System.out.println("Value of second object: " +obj2.getValue());


        System.out.println("Are both equal? " + obj1.compare(obj2));
//Compilation Error

    }
}
```

In the preceding code, the `WildCardDemo` class is created with three methods: `setValue()`, `getValue()`, and `compare()`. The `compare()` method uses wildcards so that an object of `Number` or one of its subtype can be passed to it at runtime. When the `compare()` method is called, a compilation error is raised because `obj2` is of type, `String`, and `obj1` is of type, `Integer`.

In the preceding example, the `<? extends Number>` wildcard is used, which tells that the specified object must inherit the `Number` class.



Just a minute:

Which one of the following wildcards is used to specify the type that is inherited from the specified class?

1. `<?>`
2. `<? extends >`
3. `<extends ?>`
4. `<? extends ?>`

Answer:

2. `<? extends >`

Activity 4.1: Working with Generics

Practice Questions

1. Which one of the following symbols is used to define type parameters?
   a. `{ }`
   b. `[ ]`
   c. `( )`
   d. `< >`

2. State whether the following statement is true or false.
   A non generic class can contain a generic method.

3. Identify the correct syntax of a generic class.
   a. `public <T> class Myclass { }`
   b. `public class <T> Myclass { }`
   c. `public class Myclass <T> { }`
   d. `public class Myclass {<T>}`

4. Identify the correct syntax of a generic method.
   a. `public <T> T myMethod()`
   b. `public myMethod<T> T()`
   c. `public <T> myMethod()`
   d. `public myMethod T()`

5. Which one of the following wildcards specifies that the type can be anything?
   a. `?`
   b. `? extends`
   c. `? super`
   d. `? implements`

Summary

In this chapter, you learned that:

- Generics enable you to generalize classes, which mean that a reference variable, an argument of a method, and a return type can be of any type.
- The type parameter section is represented by angular brackets, < >, that can have one or more types of parameters separated by commas.
- In the generic class, a method can use the type parameter of the class, which automatically makes the method generic.
- You can declare a generic method, which contains its own one or more type parameters.
- The declaration of a generic method contains the type parameter that is represented by angular brackets, < >.
- Java provides wildcards that allow you to achieve inheritance in a type parameter.
- Java provides a new feature, type inference, which enables you to invoke the constructor of a generic class with an empty set of type parameters, <>.
- Java provides wildcard arguments to pass a subclass as a subtype of a superclass in generics.
- Java provides the following types of wildcards:
  - `? extends`
  - `? super`
  - `?`

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Working with Collections

CHAPTER 5

At times, you need to handle a collection of objects. This task can be performed with the help of arrays. However, arrays work on a single type of data. Therefore, to work with the collection of different types of object, Java provides the collection framework. This framework provides interfaces, classes, and algorithms for implementing data structures. The collection framework is used for various purposes, such as storing, retrieving, and manipulating objects.

This chapter explains how to use various interfaces, such as `List`, `Set`, `Map`, and `Deque`, to create a collection of objects. In addition, it discuss about the sorting functionalities.

Objectives

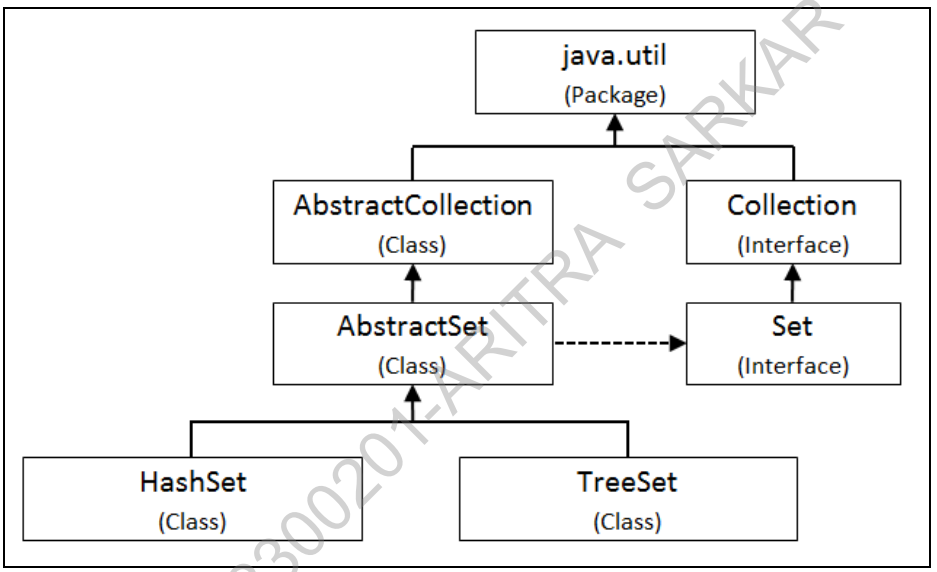
In this chapter, you will learn to:

- Use the Set interface
- Use the List interface
- Use the Map interface
- Use the Deque interface
- Implement sorting

Using the Set Interface

Consider a scenario where you need to develop a chat application. In this application, you can implement a set of functionalities to create a chat group dynamically from the list of available contacts. Further, members can be added and removed from the chat group as per the user preference. To implement this functionality, you can create a collection of contacts. However, to ensure the uniqueness of the contacts in the chat group, you need to create the collection using the `Set` interface.

The `Set` interface is used to create a collection of unique objects. The following figure shows the class hierarchy of the `java.util` package, which implements the `Set` interface.



The Class Hierarchy of the java.util Package

The preceding figure shows that the `java.util` package contains the `AbstractCollection`, `AbstractSet`, `HashSet`, and `TreeSet` classes and the `Collection` and `Set` interfaces. The `AbstractSet` class implements the `Set` interface and extends the `AbstractCollection` class, which is further extended by the `HashSet` and `TreeSet` classes. In addition, the `Set` interface extends the `Collection` interface.

The package, `java.util`, provides the `Iterator` interface to traverse through the set collection. The reference of the `Iterator` interface can be obtained using the `iterator()` method of the `Set` interface. The `Iterator` interface contains various methods, such as `hasNext()` and `next()`, which help to traverse the set collection.

Working with the HashSet Class

The `HashSet` class provides the implementation of the `Set` interface that enables you to create a set in which insertion is faster because it does not sort the elements. The `HashSet` class provides various constructors that can be used to create an instance.

The following table lists the commonly used constructors of the `HashSet` class.

Constructor	***Description***
`HashSet()`	*Creates an empty instance of `HashSet`.*
`HashSet(Collection<? extends E> c)`	*Creates an instance with the specified collection.*
`HashSet(int initialCapacity)`	*Creates an empty instance of `HashSet` with the specified initial capacity. The initial capacity is the size of `HashSet` that grows or shrinks automatically, whenever objects are added or removed to/ from `HashSet`.*

The Constructors of the HashSet Class

The following table lists the commonly used methods of the `HashSet` class.

Method	***Description***
`boolean add(E e)`	*Is used to add the specified object to `HashSet`, if it is not present. If present, it leaves `HashSet` unchanged and returns `false`.*
`void clear()`	*Is used to remove all the objects from `HashSet`.*
`boolean remove(Object o)`	*Is used to remove the specified object from `HashSet`.*
`int size()`	*Is used to get the number of objects in `HashSet`.*

The Methods of the HashSet Class

Consider the following code snippet to create a collection using a `HashSet` class:

```
import java.util.*;
class Contacts
{
  /* code to create contacts */
}
public class ChatGroup
{
```

```
    public static void main(String args[])
    {
     Contacts a=new Contacts();
     Contacts b=new Contacts();
     Contacts c=new Contacts();
     HashSet<Contacts> hs=new HashSet<Contacts>();
     hs.add(a);
     hs.add(b);
     hs.add(c);
     }
}
```

In the preceding code snippet, the generic type object of the `HashSet` class is created that contains a collection of the `Contacts` objects. The `add()` method of the `HashSet` class is used to add the `Contacts` objects to the `HashSet` object.

You can use the following code snippet to remove the `Contacts` object from the `HashSet` object:

```
hs.remove(c);
```

You can use the following code snippet to find the number of objects available in the `HashSet` object:

```
hs.size();
```

You can use the following code snippet to traverse through the `HashSet` object:

```
Iterator i = hs.iterator();
    while(i.hasNext())
    {
        System.out.println(i.next());
    }
```

In the preceding code snippet, the `iterator()` method is used to retrieve the `Iterator` reference. In addition, the `hasNext()` method is used to check if there are more elements in `HashSet`, and the `next()` method is used to retrieve the element.

You have learned how generics resolve type safety issues in the Java applications. In addition, you have also used the generic `HashSet` collection where you need to specify the type of objects that the collection would store. However, there are several existing applications that have been developed before generics were introduced and such applications should continue running. To ensure interoperability of such applications, Java also provides support for non generic collections. In the previous example, a collection of objects is created by specifying the generic type, `<Contact>`. In this context, the collection is of the `Contact` objects only. However, you can also use the non generic `HashSet` collection that can store any type of objects. For this, you can use the following code snippet:

```
Contacts a=new Contacts();
HashSet hs=new HashSet();
hs.add(a);
hs.add("String object");
hs.add(new Integer(3));
```

In the preceding code snippet, a non generic `HashSet` collection is created that contains a collection of different objects.

Note

Raw type is the name of the generic class or interface without any type arguments.

Working with the TreeSet Class

The `TreeSet` class provides the implementation of the `Set` interface that enables you to create a sorted set of objects. The insert or add object process is slow as it sorts the objects on every insertion. However, `TreeSet` automatically arranges the objects in a sorted order, which enhances the search of data from a large amount of information. The `TreeSet` class provides various constructors that can be used to create an instance of `TreeSet`. The following table lists the commonly used constructors of the `TreeSet` class.

Constructor	***Description***
`TreeSet()`	*Creates an empty instance of* `TreeSet`*.*
`TreeSet(Collection<? extends E> c)`	*Creates an instance with the specified collection.*

The Constructors of the TreeSet Class

The following table lists the commonly used methods of the `TreeSet` class.

Method	***Description***
`boolean add(E e)`	*Is used to add the specified object to* `TreeSet`*, if it is not present.*
`void clear()`	*Is used to remove all the objects from* `TreeSet`*.*
`boolean remove(Object o)`	*Is used to remove the specified object from* `TreeSet`*.*
`int size()`	*Is used to get the number of objects in* `TreeSet`*.*

The Methods of the TreeSet Class

Consider the following code to add and remove the objects to/ from a `TreeSet` collection:

```
import java.util.Iterator;
import java.util.TreeSet;

public class TreeSetDemo
{
    public static void main(String[] args)
    {
        TreeSet<Integer> obj = new TreeSet<Integer>();
        Integer iobj1 = new Integer(114);
        Integer iobj2 = new Integer(111);
        Integer iobj3 = new Integer(113);
        Integer iobj4 = new Integer(112);

        System.out.println("Size of TreeSet is: " + obj.size());

        obj.add(iobj1);
        obj.add(iobj2);
        obj.add(iobj3);
        obj.add(iobj4);
        obj.add(iobj2);

        System.out.println("\nTreeSet after adding the objects: " + obj);
        System.out.println("Size of TreeSet after adding objects: " +
obj.size());
        obj.remove(iobj3);
        obj.remove(iobj1);

        System.out.println("\nTreeSet after removing the objects: " + obj);
        System.out.println("Size of TreeSet after removing objects: " +
obj.size());

        System.out.println("\nThe final TreeSet: ");
        Iterator i = obj.iterator();
        while(i.hasNext())
        {
            System.out.println(i.next());
        }
   }
}
```

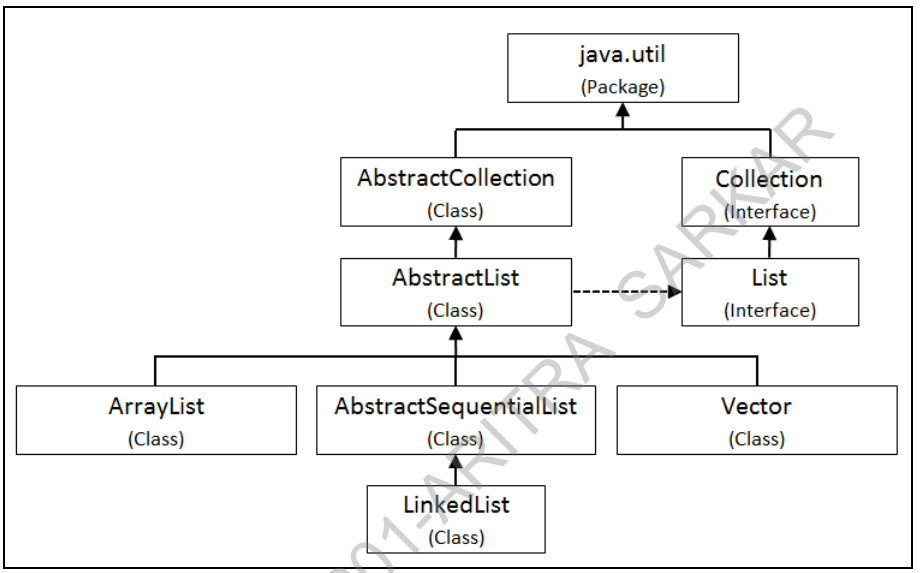
Once the preceding code is executed, the following output is displayed:

```
Size of TreeSet is: 0

TreeSet after adding the objects: [111, 112, 113, 114]
Size of TreeSet after adding objects: 4

TreeSet after removing the objects: [111, 112]
Size of TreeSet after removing objects: 2

The final TreeSet:
111
112
```

In the preceding code, the `TreeSet` object contains a collection of the `Integer` objects. The `add()` method of the `TreeSet` class is used to add the `Integer` objects to the `TreeSet` object. Further, two objects are removed using the `remove()` method. The `Iterator` interface is used to iterate the objects in the set one after the other.

Using the List Interface

The `List` interface is used to create an ordered collection of objects, which can contain duplicate objects. In this collection, the objects can be inserted one after the other or at the specified position in the list. Similarly, the objects can be accessed one after the other or from the specified position in the list. The following figure shows the class hierarchy of the `java.util` package that implements the `List` interface.



The Class Hierarchy of the java.util Package

The preceding figure shows that the `java.util` package contains the `AbstractCollection`, `AbstractList`, `ArrayList`, `AbstractSequentialList`, `Vector`, and `LinkedList` classes and the `Collection` and `List` interfaces. The `AbstractCollection` class is extended by the `AbstractList` class, which is then extended by the `ArrayList`, `AbstractSequentialList`, and `Vector` classes. The `AbstractList` class implements the `List` interface, which extends the `Collection` interface. The `LinkedList` class extends the `AbstractSequentialList` class.

The package, `java.util`, provides the `ListIterator` interface to traverse through the list collection. The reference of the `ListIterator` interface can be obtained using the `listIterator()` method of the `List` interface. The `ListIterator` interface contains various methods, such as `hasNext()`, `hasPrevious()`, `next()`, and `previous()`, which help to traverse the list in both directions.

Working with the ArrayList Class

The `ArrayList` class provides the implementation of the `List` interface. The `ArrayList` class enables you to create a resizable array. Its size increases dynamically when more elements are added. `ArrayList` proves to be efficient in searching an object in the list and inserting the objects at the end of the list.

The `ArrayList` class provides various constructors that can be used to create an instance. The following table lists the commonly used constructors of the `ArrayList` class.

Constructor	***Description***
`ArrayList()`	*Creates an empty instance of `ArrayList`.*
`ArrayList(Collection<? extends E> c)`	*Creates an instance with the specified collection.*
`ArrayList(int initialCapacity)`	*Creates an empty instance of `ArrayList` with the specified initial capacity. The initial capacity is the size of `ArrayList` that grows or shrinks automatically, whenever an object is added or removed to/ from `ArrayList`.*

The Constructors of the ArrayList Class

The following table lists the commonly used methods of the `ArrayList` class.

Method	***Description***
`boolean add(E e)`	*Is used to add the specified object at the end of `ArrayList`.*
`void clear()`	*Is used to remove all the objects from `ArrayList`.*
`E get(int index)`	*Is used to retrieve the object at the specified index from `ArrayList`.*
`E remove(int index)`	*Is used to remove the object at the specified index from `ArrayList`.*
`boolean remove(Object o)`	*Is used to remove the first occurrence of the specified object from `ArrayList`.*
`int size()`	*Is used to get the number of objects in `ArrayList`.*

The Methods of the ArrayList Class

Consider the following code to add and remove the objects to/ from an `ArrayList` collection:

```
import java.util.ArrayList;
import java.util.ListIterator;

public class ArrayListDemo
{
    public static void main(String[] args)
    {
        ArrayList<String> obj = new ArrayList<String>();
        String sobj1 = new String("Element 1");
        String sobj2 = new String("Element 2");
        String sobj3 = new String("Element 3");
        String sobj4 = new String("Element 4");

        System.out.println("Size of ArrayList is: " + obj.size());

        obj.add(sobj1);
        obj.add(sobj2);
        obj.add(sobj3);
        obj.add(sobj4);
        obj.add(sobj1);

        System.out.println("\nArrayList after adding the objects: " + obj);
        System.out.println("Size of ArrayList after adding objects: " +
obj.size());

        obj.remove(2);
        obj.remove(sobj4);

        System.out.println("\nArrayList after removing the objects: " + obj);
        System.out.println("Size of ArrayList after removing objects: " +
obj.size());

        System.out.println("\nThe final ArrayList: ");
        ListIterator i = obj.listIterator();
        while(i.hasNext())
        {
            System.out.println(i.next());
        }
    }
}
```

In the preceding code, the `ArrayList` object contains a collection of the `String` objects. The `add()` method of the `ArrayList` class is used to add the `String` objects. Further, two objects are removed using the `remove()` method. The `ListIterator` interface is used to iterate the objects in the list one after the other.

Once the preceding code is executed, the following output is displayed:

```
Size of ArrayList is: 0

ArrayList after adding the objects: [Element 1, Element 2, Element 3, Element
4, Element 1]
Size of ArrayList after adding objects: 5

ArrayList after removing the objects: [Element 1, Element 2, Element 1]
Size of ArrayList after removing objects: 3

The final ArrayList:
Element 1
Element 2
Element 1
```

Working with the LinkedList Class

The `LinkedList` class provides the implementation of the `List` interface. The `LinkedList` class enables you to create a *doubly-linked list*. The doubly-linked list is a set of sequentially linked records called nodes where each node contains two links that are the references of the previous node and the next node in the sequence, respectively. `LinkedList` can be traversed in the forward or backward direction. `LinkedList` proves to be efficient in insertion and deletion of objects from the list.

The `LinkedList` class provides various constructors that can be used to create an instance. The following table lists the commonly used constructor of the `LinkedList` class.

Constructor	***Description***
`LinkedList()`	*Creates an empty instance of `LinkedList`.*
`LinkedList(Collection<? extends E> c)`	*Creates an instance with the specified collection.*

The Constructors of the LinkedList Class

The following table lists the commonly used methods of the `LinkedList` class.

Method	***Description***
`boolean add(E e)`	*Is used to add the specified object at the end of `LinkedList`.*
`void clear()`	*Is used to remove all the objects from `LinkedList`.*
`E get(int index)`	*Is used to retrieve the object at the specified index from `LinkedList`.*

Method	*Description*
`E remove(int index)`	*Is used to remove the object at the specified index from* `LinkedList`*.*
`boolean remove(Object o)`	*Is used to remove the first occurrence of the specified object from* `LinkedList`*.*
`int size()`	*Is used to get the number of objects in* `LinkedList`*.*

The Methods of the LinkedList Class

Consider the following code to add and remove the objects to/ from a `LinkedList` collection:

```
import java.util.LinkedList;
import java.util.ListIterator;

public class LinkedListDemo
{
    public static void main(String[] args)
    {
        LinkedList<Integer> obj = new LinkedList<Integer>();
        Integer iobj1 = new Integer(101);
        Integer iobj2 = new Integer(102);
        Integer iobj3 = new Integer(103);
        Integer iobj4 = new Integer(104);
        System.out.println("Size of LinkedList is: " + obj.size());
        obj.add(iobj1);
        obj.add(iobj2);
        obj.add(iobj3);
        obj.add(iobj4);
        obj.add(iobj1);

        System.out.println("\nLinkedList after adding the objects: " + obj);
        System.out.println("Size of LinkedList after adding objects: " +
obj.size());

        obj.remove(iobj2);
        obj.remove(iobj3);

        System.out.println("\nLinkedList after removing the objects: " +
obj);
        System.out.println("Size of LinkedList after removing objects: " +
obj.size());

        System.out.println("\nThe final LinkedList: ");
        ListIterator i = obj.listIterator();
        while(i.hasNext())
        {
            System.out.println(i.next());
        }
    }
}
```

Once the preceding code is executed, the following output is displayed:

```
Size of LinkedList is: 0

LinkedList after adding the objects: [101, 102, 103, 104, 101]
Size of LinkedList after adding objects: 5

LinkedList after removing the objects: [101, 104, 101]
Size of LinkedList after removing objects: 3


The final LinkedList:
101
104
101
```

In the preceding code, the `LinkedList` object contains a collection of the `Integer` objects. The `add()` method of the `LinkedList` class is used to add the `Integer` objects. Further, two objects are removed using the `remove()` method. The `ListIterator` interface is used to iterate the objects in the list one after the other.

Working with the Vector Class

The `Vector` class is similar to the `ArrayList` and `LinkedList` classes. However, the methods of the `Vector` class are synchronized, which means that only one thread at a given time can access it in a multithreaded environment. On the other hand, the methods of the `ArrayList` and `LinkedList` classes are not synchronized.

The `Vector` class provides various constructors that can be used to create an instance. The following table lists the commonly used constructors of the `Vector` class.

Constructor	***Description***
`Vector()`	*Creates an empty instance of `Vector`.*
`Vector(Collection<? extends E> c>`	*Creates an instance with the specified collection.*
`Vector(int initialCapacity)`	*Creates an empty instance of `Vector` with the specified initial capacity. The initial capacity is the size of `Vector` that grows or shrinks automatically, whenever an object is added or removed to/ from `Vector`.*

The Constructors of the Vector Class

The following table lists the commonly used methods of the `Vector` class.

Method	***Description***
`boolean add(E e)`	*Is used to add the specified object at the end of `Vector`.*
`void clear()`	*Is used to remove all the objects from `Vector`.*
`E get(int index)`	*Is used to retrieve the object at the specified index from `Vector`.*
`E remove(int index)`	*Is used to remove the object at the specified index from `Vector`.*
`boolean remove(Object o)`	*Is used to remove the first occurrence of the specified object from `Vector`.*
`int size()`	*Is used to get the number of objects in `Vector`.*

The Methods of the Vector Class

Consider the following code to add and remove the objects to/ from a `Vector` collection:

```
import java.util.ListIterator;
import java.util.Vector;
public class VectorDemo
{
    public static void main(String[] args)
    {
        Vector<Double> obj = new Vector<Double>();
        Double dobj1 = new Double(77.5);
        Double dobj2 = new Double(68.1);
        Double dobj3 = new Double(52.8);
        Double dobj4 = new Double(40.2);

        System.out.println("Size of Vector is: " + obj.size());

        obj.add(dobj1);
        obj.add(dobj2);
        obj.add(dobj3);
        obj.add(dobj4);
        obj.add(dobj1);

        System.out.println("\nVector after adding the objects: " + obj);
        System.out.println("Size of Vector after adding objects: " +
obj.size());

        obj.remove(dobj1);
        obj.remove(dobj3);
```

```
        System.out.println("\nVector after removing the objects: " + obj);
        System.out.println("Size of Vector after removing objects: " +
obj.size());

        System.out.println("\nThe final Vector: ");
        ListIterator i = obj.listIterator();
        while(i.hasNext())
        {
            System.out.println(i.next());
        }
    }
}
```

Once the preceding code is executed, the following output is displayed:

```
Size of Vector is: 0

Vector after adding the objects: [77.5, 68.1, 52.8, 40.2, 77.5]
Size of Vector after adding objects: 5

Vector after removing the objects: [68.1, 40.2, 77.5]
Size of Vector after removing objects: 3

The final Vector:
68.1
40.2
```

In the preceding code, the `Vector` object contains a collection of the `Double` objects. The `add()` method of the `Vector` class is used to add the `Double` objects. Further, two objects are removed using the `remove()` method. The `ListIterator` interface is used to iterate the objects one after the other.

Just a minute:

Which one of the following classes enables you to create a collection of unique objects?

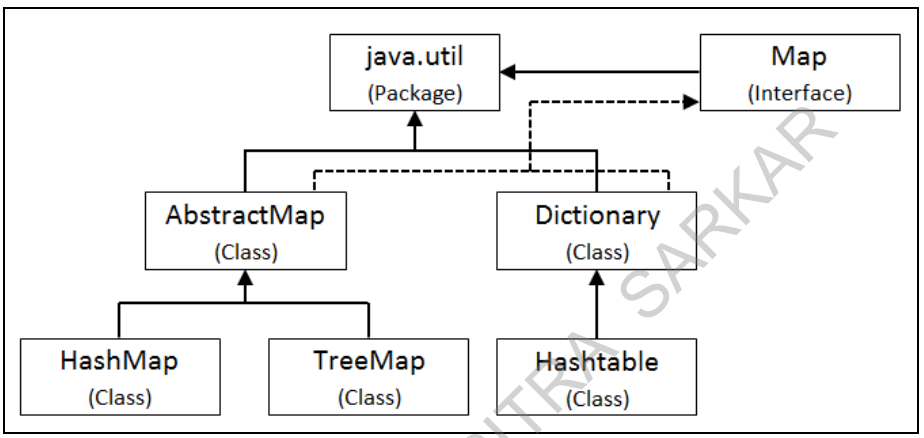
1. *List*
2. *Vector*
3. *TreeSet*
4. *ArrayList*

Answer:

3. *TreeSet*

Using the Map Interface

The `Map` interface enables you to create a collection with key-value pair objects. In this collection, both key and value are objects. You need to use the key object to access the corresponding value object. The `Map` interface allows duplicate value objects but the key object must be unique. The following figure shows the class hierarchy of the `java.util` package that implements the `Map` interface.



The Class Hierarchy of the java.util Package

The preceding figure shows that the `java.util` package contains the `AbstractMap`, `Dictionary`, `HashMap`, `TreeMap`, and `Hashtable` classes and the `Map` interface. The `HashMap` and `TreeMap` classes extend the `AbstractMap` class, which implements the `Map` interface. In addition, the `Hashtable` class extends the `Dictionary` class that also implements the `Map` interface.

Working with the HashMap Class

The `HashMap` class enables you to create a collection in which a value is accessible using the key. `HashMap` stores objects in an unordered form. The `HashMap` class allows one `null` value for a key and any number of `null` values for values.

The `HashMap` class provides various constructors that can be used to create an instance.

The following table lists the commonly used constructors of the `HashMap` class.

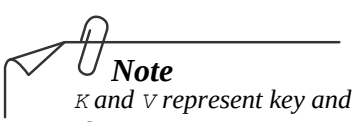
Constructor	***Description***
`HashMap()`	*Creates an empty instance of* `HashMap`*.*
`HashMap(int initialCapacity)`	*Creates an empty instance of* `HashMap` *with the specified initial capacity. The initial capacity is the size of* `HashMap` *that grows or shrinks automatically, whenever objects are added or removed to/ from* `HashMap`*.*
`HashMap(Map<? extends K, ? extends V> m)`	*Creates an instance with the same mapping of specified* `Map`*.*

The Constructors of the HashMap Class

The following table lists the commonly used methods of the `HashMap` class.

Method	***Description***
`void clear()`	*Is used to remove all the mapping from* `HashMap`*.*
`V get(Object key)`	*Is used to get the value object of the specified key object from* `HashMap`*.*
`V put(K key, V value)`	*Is used to add the specified key object with the specified value object in* `HashMap`*.*
`V remove(Object o)`	*Is used to remove the mapping for the specified key object from* `HashMap`*.*
`int size()`	*Is used to get the number of key-value mappings in* `HashMap`*.*

The Methods of the HashMap Class



Note

`K` and `V` represent key and value, respectively. Both, `K` and `V`, are used for the types of classes.

Consider the following code to add and remove the objects to/ from a `HashMap` collection:

```
import java.util.HashMap;

public class HashMapDemo
{
    public static void main(String[] args)
    {
        HashMap<String, Integer> obj = new HashMap<String, Integer>();
        Integer iobj1 = new Integer(11);
        Integer iobj2 = new Integer(22);
        Integer iobj3 = new Integer(33);
        Integer iobj4 = new Integer(44);

        System.out.println("Size of HashMap is: " + obj.size());

        obj.put("L1", iobj1);
        obj.put("L2", iobj2);
        obj.put("L3", iobj3);
        obj.put("L4", iobj4);
        obj.put("L5", iobj1);

        System.out.println("\nHashMap after adding the objects: " + obj);
        System.out.println("Size of HashMap after adding objects: " +
obj.size());

        obj.remove("L3");
        obj.remove("L5");

        System.out.println("\nHashMap after removing the objects: " + obj);
        System.out.println("Size of the HashMap after removing objects: " +
obj.size());
    }
}
```

Once the preceding code is executed, the following output is displayed:

```
Size of HashMap is: 0

HashMap after adding the objects: {L1=11, L2=22, L3=33, L4=44, L5=11}
Size of HashMap after adding objects: 5

HashMap after removing the objects: {L1=11, L2=22, L4=44}
Size of the HashMap after removing objects: 3
```

In the preceding code, the `HashMap` object contains a collection of key-value pair objects. The `put()` method of the `HashMap` class is used to add the key-value pair objects. Further, the mapping of two objects are removed using the `remove()` method.

Working with the TreeMap Class

The `TreeMap` class enables you to create a collection of objects in the sorted order with unique keys. The sorted collection improves the retrieval process of objects.

The `TreeMap` class provides various constructors that can be used to create an instance. The following table lists commonly used constructors of the `TreeMap` class.

Constructor	***Description***
`TreeMap()`	*Creates an instance with empty `TreeMap`.*
`TreeMap(Map<? extends K, ? extends V> m)`	*Creates an instance with the same mapping of specified `Map`.*

The Constructors of the TreeMap Class

The following table lists the commonly used methods of the `TreeMap` class.

Method	***Description***
`void clear()`	*Is used to remove all the mapping from `TreeMap`.*
`V get(Object key)`	*Is used to get the value object of the specified key object from `TreeMap`.*
`V put(K key, V value)`	*Is used to add the specified key object with the specified value object in `TreeMap`.*
`V remove(Object o)`	*Is used to remove the mapping for the specified key object from `TreeMap`.*
`int size()`	*Is used to get the number of key-value mapping in `TreeMap`.*

The Methods of the TreeMap Class

Consider the following code to add and remove the objects to/ from a `TreeMap` collection:

```
import java.util.TreeMap;

public class TreeMapDemo
{
    public static void main(String[] args)
    {
        TreeMap<Integer, String> obj = new TreeMap<Integer, String>();
        String sobj1 = new String("Value 1");
        String sobj2 = new String("Value 2");
        String sobj3 = new String("Value 3");
```

```
        String sobj4 = new String("Value 4");
        System.out.println("Size of TreeMap is: " + obj.size());
        obj.put(101, sobj1);
        obj.put(102, sobj2);
        obj.put(103, sobj3);
        obj.put(104, sobj4);
        obj.put(105, sobj1);
        System.out.println("\nTreeMap after adding the objects: " + obj);
        System.out.println("Size of TreeMap after adding objects: " +
obj.size());
        obj.remove(103);
        obj.remove(105);
        System.out.println("\nTreeMap after removing the objects: " + obj);
        System.out.println("Size of the TreeMap after removing objects: " +
obj.size());
    }
}
```

Once the preceding code is executed, the following output is displayed:

```
Size of TreeMap is: 0

TreeMap after adding the objects: {101=Value 1, 102=Value 2, 103=Value 3,
104=Value 4, 105=Value 1}
Size of TreeMap after adding objects: 5

TreeMap after removing the objects: {101=Value 1, 102=Value 2, 104=Value 4}
Size of the TreeMap after removing objects: 3
```

In the preceding code, the `TreeMap` object contains a collection of key-value pair objects. The `put()` method of the `TreeMap` class is used to add the key-value pair objects. Further, mapping of two objects are removed using the `remove()` method.

Working with the Hashtable Class

The `Hashtable` class enables you to create an unordered collection of objects, which cannot contain the `null` objects. The methods of the `Hashtable` class are synchronized, which means that only one thread at a given time can access it in a multithreaded environment. On the other hand, the methods of the `HashMap` and `TreeMap` classes are not synchronized.

The `Hashtable` class provides various constructors that can be used to create an instance.

The following table lists commonly used constructors of the `Hashtable` class.

Constructor	***Description***
`Hashtable()`	*Creates an instance with empty `Hashtable`.*
`Hashtable(int initialCapacity)`	*Creates an instance with empty `Hashtable` with the specified initial capacity. The initial capacity is the size of `Hashtable` that grows or shrinks automatically, whenever objects are added or removed to/ from `Hashtable`.*
`Hashtable(Map<? extends K, ? extends V> t)`	*Creates an instance with the same mapping of specified `Map`.*

The Constructors of the Hashtable Class

The following table lists the commonly used methods of the `Hashtable` class.

Method	***Description***
`void clear()`	*Is used to remove all objects from `Hashtable`.*
`V get(Object key)`	*Is used to get the value object of the specified key object from `Hashtable` or `null` if it does not contain any value for the specified key object.*
`V put(K key, V value)`	*Is used to add the specified key object with the specified value object in `Hashtable`.*
`V remove(Object o)`	*Is used to remove the mapping for the specified key object from `Hashtable`.*
`int size()`	*Is used to get the number of keys in `Hashtable`.*

The Methods of the Hashtable Class

Consider the following code to add and remove the objects to/ from a `Hashtable` collection:

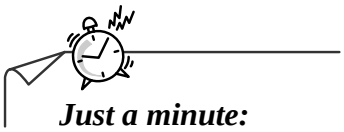
```
import java.util.Hashtable;

public class HashtableDemo
{
    public static void main(String[] args)
    {
        Hashtable<Integer, Double> obj = new Hashtable<Integer, Double>();
        Double dobj1 = new Double(55.6);
        Double dobj2 = new Double(34.6);
        Double dobj3 = new Double(98.6);
```

```
        Double dobj4 = new Double(12.5);

        System.out.println("Size of Hashtable is: " + obj.size());

        obj.put(55, dobj1);
        obj.put(60, dobj2);
        obj.put(65, dobj3);
        obj.put(70, dobj4);
        obj.put(75, dobj3);

        System.out.println("\nHashtable after adding the objects: " + obj);
        System.out.println("Size of Hashtable after adding objects: " +
obj.size());

        obj.remove(65);
        obj.remove(75);

        System.out.println("\nHashtable after removing the objects: " + obj);
        System.out.println("Size of Hashtable after removing objects: " +
obj.size());

    }
}
```

Once the preceding code is executed, the following output is displayed:

```
Size of Hashtable is: 0

Hashtable after adding the objects: {65=98.6, 75=98.6, 60=34.6, 70=12.5,
55=55.6}
Size of Hashtable after adding objects: 5

Hashtable after removing the objects: {60=34.6, 70=12.5, 55=55.6}
Size of Hashtable after removing objects: 3
```

In the preceding code, the `Hashtable` object contains a collection of key-value pair objects. The `put()` method of the `Hashtable` class is used to add the key-value pair objects. Further, mapping of two objects are removed using the `remove()` method.



Just a minute:

Which one of the following classes contains the synchronized methods?

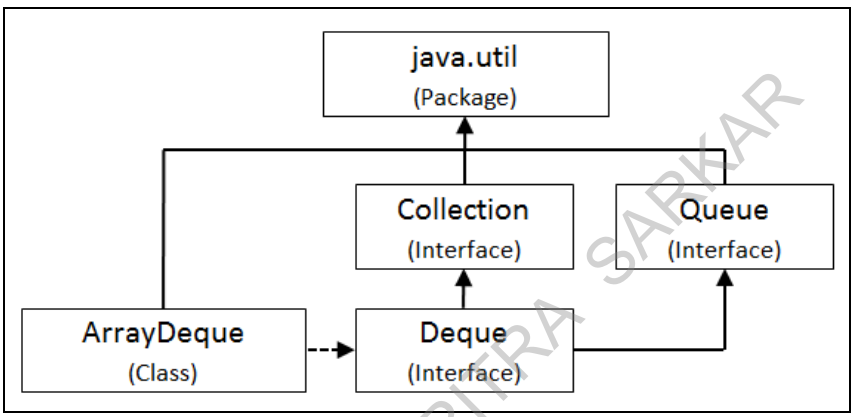
1. `Hashtable`
2. `HashSet`
3. `TreeMap`
4. `ArrayList`

Answer:

1. `Hashtable`

Using the Deque Interface

The `Deque` interface allows you to create a collection of objects in which the objects can be inserted or deleted from both ends. `Deque` is the short form for the double-ended queue. The `Deque` interface extends the `Queue` interface that provides the collection in which objects are inserted at the end and deleted from the beginning. The `Queue` interface mainly works on the First In First Out (FIFO) algorithm. The following figure shows the class hierarchy of the `java.util` package that implements the `Deque` interface.



The Class Hierarchy of the java.util Package

The preceding figure shows that the `java.util` package contains the `ArrayDeque` class and the `Collection`, `Queue`, and `Deque` interfaces. The `ArrayDeque` class implements the `Deque` interface that is extended from the `Collection` and `Queue` interfaces.

Working with the ArrayDeque Class

The `ArrayDeque` class provides an implementation of the `Deque` interface that enables you to create a resizable array, which allows insertion and deletion from both the ends. However, the methods of the `ArrayDeque` class are not synchronized, which means more than one thread at a given time can access it in a multithreaded environment.

The `ArrayDeque` class provides various constructors that can be used to create an instance.

The following table lists the commonly used constructors of the `ArrayDeque` class.

Constructor	***Description***
`ArrayDeque()`	*Creates an empty instance of* `ArrayDeque`*.*
`ArrayDeque(Collection<? extends E> c)`	*Creates an instance with the specified collection.*
`ArrayDeque(int numElement)`	*Creates an empty instance of* `ArrayDeque` *with the initial capacity that can hold the specified number of elements.*

The Constructors of the ArrayDeque Class

The following table lists the commonly used methods of the `ArrayDeque` class.

Method	***Description***
`boolean add(E e)`	*Is used to add the specified object at the end of* `ArrayDeque`*.*
`void addFirst(E e)`	*Is used to add the specified object as the first element in* `ArrayDeque`*.*
`void addLast(E e)`	*Is used to add the specified object as the last element in* `ArrayDeque`*.*
`void clear()`	*Is used to remove all the objects from* `ArrayDeque`*.*
`E getFirst()`	*Is used to retrieve the first object of* `ArrayDeque`*.*
`E getLast()`	*Is used to retrieve the last element of* `ArrayDeque`*.*
`E removeFirst()`	*Is used to retrieve and remove the first object from* `ArrayDeque`*.*
`E removeLast()`	*Is used to retrieve and remove the last object from* `ArrayDeque`*.*
`int size()`	*Is used to retrieve the number of objects in* `ArrayDeque`*.*

The Methods of the ArrayDeque Class

Consider the following code to add and remove the objects to/ from an `ArrayDeque` collection:

```
import java.util.ArrayDeque;

public class ArrayDequeDemo
{
    public static void main(String[] args)
    {
        ArrayDeque<Double> obj = new ArrayDeque<Double>();
        Double dobj1 = new Double(7.5);
        Double dobj2 = new Double(8.5);
        Double dobj3 = new Double(9.5);
        Double dobj4 = new Double(10.5);

        System.out.println("Size of ArrayDeque is: " + obj.size());

        obj.add(dobj1);
        obj.add(dobj2);

        System.out.println("\nArrayDeque after adding the objects: " + obj);
        System.out.println("Size of ArrayDeque after adding objects: " +
obj.size());

        obj.addFirst(dobj3);
        obj.addLast(dobj4);

        System.out.println("\nArrayDeque after adding the objects at first
and last: " + obj);
        System.out.println("Size of ArrayDeque after adding objects at first
and last: " + obj.size());

        obj.removeFirst();

        System.out.println("\nArrayDeque after removing the first object: " +
obj);
        System.out.println("Size of ArrayDeque after removing the first
objects: " + obj.size());
    }
}
```

Once the preceding code is executed, the following output is displayed:

```
Size of ArrayDeque is: 0

ArrayDeque after adding the objects: [7.5, 8.5]
Size of ArrayDeque after adding objects: 2

ArrayDeque after adding the objects at first and last: [9.5, 7.5, 8.5, 10.5]
Size of ArrayDeque after adding objects at first and last: 4

ArrayDeque after removing the first object: [7.5, 8.5, 10.5]
Size of ArrayDeque after removing the first objects: 3
```

In the preceding code, the `ArrayDeque` object contains a collection of the `Double` objects. The `add()` method of the `ArrayDeque` class is used to add the `Double` objects to the `Deque` object. Two objects are added, one at the beginning and the other at the end of the queue. Further, an object is removed using the `remove()` method, and the `removeFirst()` method is used to remove the element stored at the first position.

Implementing Sorting

Consider a scenario of Address Book, which contains the contact details, such as name, contact number, and address. Now, you need to create a list of contacts living in Asia. In addition, you need to ensure that the list should have the flexibility to add or remove any number of contacts. For this, you have decided to create a collection of contacts. Thereafter, you need to sort the list according to the contact name. For this, Java provides the following interfaces to sort the objects in a collection:

- The `Comparable` interface
- The `Comparator` interface

The `Comparable` and `Comparator` interfaces provide their own methods to achieve the sorting on the collection. However, the `Comparable` and `Comparator` interfaces are used with the `sort()` method of the `Collections` and `Arrays` classes to sort the collection of objects.

Using the Comparable Interface

The `Comparable` interface is defined in the `java.lang` package and is used to sort and compare a collection of objects. This interface provides the `compareTo()` method that compares the references of the objects. The `compareTo()` method returns a value of the `int` type with the following characteristics:

- **Negative**: If the current object is less than the object being compared
- **Zero**: If the current object is equal to the object being compared
- **Positive**: If the current object is greater than the object being compared

Consider the example where you want to store the name and marks of students. Thereafter, you want to sort the details of each student based on marks. For this, you have decided to create the `Student` class, as shown in the following code:

```
public class Student implements Comparable
{
    private String name;
    private int marks;

    public Student(String nm, int mk)
    {
        this.name = nm;
        this.marks = mk;
    }

    public int getMarks()
    {
        return marks;
    }
    public String getName() {
        return name;
    }
```

```
    public void setName(String name) {
        this.name = name;
    }
    public int compareTo(Object obj)
    {
        Student s = (Student) obj;

        if (this.marks > s.getMarks())
            return 1;
        else if (this.marks < s.getMarks())
            return -1;
        else
            return 0;

    }

    public String toString()
    {
        StringBuffer buffer = new StringBuffer();
        buffer.append("Name: "+ name +"\n");
        buffer.append("Marks: " + marks + "\n");
        return buffer.toString();
    }

}
```

In the preceding code, the `Student` class is created, which overrides the `compareTo()` method of the `Comparable` interface. The `compareTo()` method compares the `Student` object on the basis of marks. In addition, the `toString()` method of the `Object` class is overridden so that the name and marks of the student are displayed when the object of the `Student` class is used inside the `println()` method.

Thereafter, you can use the following code to create the `ComparableDemo` class:

```
import java.util.ArrayList;
import java.util.Collections;
import java.util.ListIterator;

public class ComparableDemo
{
    public static void main(String[] args)
    {
        Student s1 = new Student("Alex", 88);
        Student s2 = new Student("Bob", 90);
        Student s3 = new Student("Joe", 78);

        ArrayList<Student> obj = new ArrayList<>();
        obj.add(s1);
        obj.add(s2);
        obj.add(s3);

        System.out.println("Student details are:");
```

```
            ListIterator li = obj.listIterator();
            while(li.hasNext())
            {
                System.out.println(li.next());
            }

            Collections.sort(obj);

            System.out.println("Student details after sorting are:");

            ListIterator li2 = obj.listIterator();
            while(li2.hasNext())
            {
                System.out.println(li2.next());
            }
        }
    }
```

Once the preceding code is executed, the following output is displayed:

```
Student details after sorting are:
Name: Joe
Marks: 78

Name: Alex
Marks: 88

Name: Bob
Marks: 90
```

In the preceding code, the `ComparableDemo` class is created that creates an array list of three `Student` objects by adding the objects through the `add()` method. In addition, the array list is sorted using the `sort()` method of the `Collections` class.

Using the Comparator Interface

You have learned that the `Comparable` interface is used to sort and compare a collection of objects. However, by using this interface, you cannot define the logic for multiple sorting. For example, in the previous scenario, you want to create a sorting logic based on the student marks and names. For this, you can use the `Comparator` interface that is defined in the `java.util` package. This interface provides the `compare()` method that is used to compare two objects in a collection. The `compare()` method returns the value of `int` type with the following characteristics:

- **Negative**: If the current object is less than the object being compared
- **Zero**: If the current object is equal to the object being compared
- **Positive**: If the current object is greater than the object being compared

Consider the following code to define the `Student` class:

```
public class Student
{
    private String name;
    private int marks;

    public Student(String nm, int mk)
    {
        this.name = nm;
        this.marks = mk;
    }
    public int getMarks()
    {
        return marks;
    }
    public String getName() {
        return name;
    }

    public void setName(String name) {
        this.name = name;
    }
    public String toString()
    {
        StringBuffer buffer = new StringBuffer();
        buffer.append("Name: "+ name +"\n");
        buffer.append("Marks: " + marks + "\n");
        return buffer.toString();
    }

}
```

In the preceding code, `name` and `marks` are the attributes of the `Student` class. In addition, the setter and getter methods for the attributes are defined. Further, the `toString()` method of the `Object` class is overridden.

Consider the following code that defines a sorting logic based on the marks of a student:

```
import java.util.Comparator;
public class MarkCompare implements Comparator{
    public int compare(Object a, Object b)
    {
        Student x = (Student) a;
        Student y = (Student) b;

        if (x.getMarks() > y.getMarks())
            return 1;
        else if (x.getMarks() < y.getMarks())
            return -1;
        else
            return 0;
    }
}
```

In the preceding code, the `compare()` method of the `Comparator` interface is overridden and the logic to sort the student objects based on the student marks is defined.

Consider the following code to define a sorting logic based on the names of students:

```
import java.util.Comparator;
public class NameCompare implements Comparator{
    public int compare(Object a, Object b)
    {
        Student x = (Student) a;
        Student y = (Student) b;
        return x.getName().compareTo(y.getName());
    }
}
```

In the preceding code, the `compare()` method of the `Comparator` interface is overridden and the logic to sort student objects based on the student names is defined. Because the name of the students are the `String` objects, the `compare()` method of the `String` class is used to implement the sorting logic.

Thereafter, you can use the following code to create a `ComparatorDemo` class:

```
import java.util.ArrayList;
import java.util.Collections;
import java.util.ListIterator;

public class ComparatorDemo
{
    public static void main(String[] args)
    {
        Student s1 = new Student("Alex", 88);
        Student s2 = new Student("Bob", 90);
        Student s3 = new Student("Joe", 78);

        ArrayList<Student> obj = new ArrayList<>();
        obj.add(s1);
        obj.add(s2);
        obj.add(s3);

        System.out.println("Student details are:");

        ListIterator li = obj.listIterator();
        while(li.hasNext())
        {
            System.out.println(li.next());
        }

        Collections.sort(obj, new MarkCompare());

        System.out.println("Mark wise sort:");

        ListIterator li2 = obj.listIterator();
        while(li2.hasNext())
        {
            System.out.println(li2.next());
        }
```

```
            Collections.sort(obj, new NameCompare());

            System.out.println("Name wise sort:");

            ListIterator li3 = obj.listIterator();
            while(li3.hasNext())
            {
                System.out.println(li3.next());
            }
        }
    }
```

Once the preceding code is executed, the following output is displayed:

```
Student details are:
Name: Alex
Marks: 88

Name: Bob
Marks: 90

Name: Joe
Marks: 78

Mark wise sort:
Name: Joe
Marks: 78

Name: Alex
Marks: 88

Name: Bob
Marks: 90

Name wise sort:
Name: Alex
Marks: 88

Name: Bob
Marks: 90

Name: Joe
Marks: 78
```

In the preceding code, the `ComparatorDemo` class is created that creates an array list of three `Student` objects by adding the objects through the `add()` method. In addition, the array list is sorted using the `sort()` method of the `Collections` class.

Activity 5.1: Working with Collections

Practice Questions

1. Which one of the following classes implements the `List` interface?
   a. `HashSet`
   b. `TreeSet`
   c. `Hashtable`
   d. `Vector`

2. Which one of the following classes is inherited from the `Dictionary` class?
   a. `HashSet`
   b. `TreeSet`
   c. `Hashtable`
   d. `HashMap`

3. Which one of the following interfaces enables you to traverse the list of objects?
   a. `Iterator`
   b. `List`
   c. `Collection`
   d. `Comparable`

4. Which one of the following methods is used to add the objects in `TreeMap`?
   a. `put()`
   b. `add()`
   c. `addObject()`
   d. `putObject()`

5. Which one of the following interfaces is used to create a collection of unique objects?
   a. `Set`
   b. `Map`
   c. `Deque`
   d. `List`

Summary

In this chapter, you learned that:

- The `Set` interface is used to create a collection of unique objects.
- The package, `java.util`, provides the `Iterator` interface to traverse through the set collection.
- The `HashSet` class provides the implementation of the `Set` interface that enables you to create a set in which insertion is faster because it does not sort the elements.
- The `TreeSet` class provides the implementation of the `Set` interface that enables you to create a sorted set of objects.
- The `List` interface is used to create an ordered collection of objects, which can contain duplicate objects.
- The package, `java.util`, provides the `ListIterator` interface to traverse through the list collection.
- The `ArrayList` class provides the implementation of the `List` interface. The `ArrayList` class enables you to create a resizable array.
- The `LinkedList` class provides the implementation of the `List` interface. The `LinkedList` class enables you to create a doubly-linked list.
- `LinkedList` can be traversed in the forward or backward direction.
- The `Vector` class is similar to the `ArrayList` and `LinkedList` classes.
- The methods of the `Vector` class are synchronized, which means that only one thread at a given time can access it in a multithreaded environment.
- The methods of the `ArrayList` and `LinkedList` classes are not synchronized.
- The `Map` interface enables you to create a collection with key-value pair objects.
- The `Map` interface allows duplicate value objects but the key object must be unique.
- The `HashMap` class enables you to create a collection in which a value is accessible using the key. `HashMap` stores objects in an unordered form.
- The `TreeMap` class enables you to create a collection of objects in the sorted order with unique keys.
- The `Hashtable` class enables you to create an unordered collection of objects, which cannot contain the `null` objects.
- The methods of the `Hashtable` class are synchronized, which means that only one thread at a given time can access it in a multithreaded environment.
- The methods of the `HashMap` and `TreeMap` classes are not synchronized.
- The `Deque` interface allows you to create a collection of objects in which the objects can be inserted or deleted from both ends.
- The `ArrayDeque` class provides an implementation of the `Deque` interface that enables you to create a resizable array, which allows insertion and deletion from both the ends.
- The methods of the `ArrayDeque` class are not synchronized, which means more than one thread at a given time can access it in a multithreaded environment.

- Java provides the following interfaces to sort the objects in a collection:
  - The `Comparable` interface
  - The `Comparator` interface
- The `Comparable` interface is defined in the `java.lang` package and is used to sort and compare a collection of objects. This interface provides the `compareTo()` method that compares the references of the objects.
- The `Comparator` interface is defined in the `java.util` package. This interface provides the `compare()` method that is used to compare two objects in a collection.

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Working with Threads

CHAPTER 6

Most computer games use graphics and sounds. The graphics, score, and audio effects are presented simultaneously. Imagine a computer game where you first see the screen changing, then you see your scores that are being updated, and finally, you hear the sound effects. In order to appreciate and enjoy a game, all these elements need to be processed simultaneously. In other words, the program should be able to efficiently perform three tasks simultaneously. In Java, you can achieve the preceding functionality by making use of *threads*. The game can be divided into three subunits that can be executed in parallel by using individual threads.

This chapter discusses how to create multithreaded applications in Java. In addition, it discusses about the thread priorities.

Objectives

In this chapter, you will learn to:

- Use threads in Java
- Create threads

Using Threads in Java

A thread can be defined as a single sequential flow of control within a program. It is a sequence of instructions that is executed to define a unique flow of control. For example, a Central Processing Unit (CPU) performs various processes simultaneously, such as writing and printing a document, installing software, and displaying the date and time. All these processes are handled by separate threads. An application comprises one or more processes that can be performed simultaneously. Further, each process is broken into small chunks known as tasks. Each thread is assigned a unique task to perform, independently. For example, a text editor is an application that allows you to perform two tasks, such as write to a document and print a document, simultaneously.

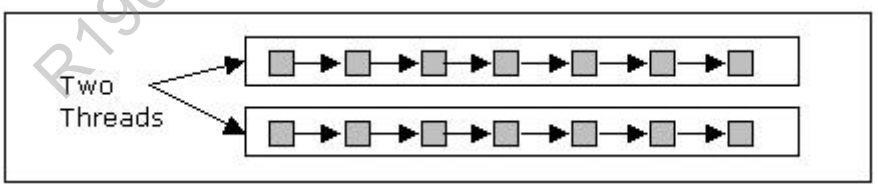
Further, you can implement multithreading in an application to achieve an efficient performance and utilize the CPU processing capabilities. In order to implement multithreading, Java provides the `Thread` class. In order to work with threads, you need to first identify their life cycle.

The Basic Concept of Multithreading

A single-threaded application can perform only one task at a time. The following figure shows a single-threaded application.

A Single-threaded Application

A single-threaded application needs to wait for one task to complete before another can start. As a result, the efficiency of the application is hampered. On the other hand, you can apply multithreading when there is a requirement to enable an application to perform several tasks simultaneously. Multithreading helps to perform multiple tasks simultaneously, which saves time and improves the execution speed and efficiency of the application. Every application has at least one thread and you can create more threads, if required. The following figure shows a multi-threaded application.



A Multi-threaded Application

The microprocessor allocates the memory to the processes that are executed by an application and each process occupies its own address space or memory. However, all the threads in a process occupy the same address space.

Advantages and Disadvantages of Multithreading

Most of the computers today utilize software and hardware, such as operating system and multiple processors that support multithreading. Therefore, to achieve efficiency and ensure an optimized performance, most of the applications utilize multhreading. However, there are certain advantages and disadvantages of using multithreading that can be identified. The various advantages of multithreading are:

- **Improved performance**: Provides improvement in the performance of the processor by the simultaneous execution of computation and Input/Output (I/O) operations.
- **Minimized system resource usage**: Minimizes the use of system resources by using threads, which share the same address space and belong to the same process.
- **Program structure simplification**: Simplifies the structure of complex applications, such as multimedia applications. Subprograms can be written for each activity that makes a complex program easy to design and code.

The various disadvantages of multithreading are:

- **Race condition**: When two or more threads simultaneously access the same variable and at least one thread tries to write a value to the variable, it is called the race condition. This condition is caused when synchronization between the two threads is not implemented. For example, in a word processor program, there are two threads, ThreadA and ThreadB. ThreadA wants to read a file, and at the same time, ThreadB wants to write to a file. If ThreadA reads the value before ThreadB performs a write operation, ThreadA will fail to receive the updated value from the file. Such a condition is known as a race condition.
- **Deadlock condition**: The *deadlock* condition arises in a computer system when two threads wait for each other to complete the operations before performing the individual action. As a result, the two threads are locked and the program fails. For example, consider two threads, ThreadA and ThreadB. ThreadA is waiting for a lock to be released by ThreadB, and ThreadB is also waiting for the lock to be released by ThreadA to complete its transaction. This situation is a deadlock condition.
- **Lock starvation**: *Lock starvation* occurs when the execution of a thread is postponed because of its low priority. JRE executes threads based on their priority because the CPU can execute only one thread at a time. The thread with a higher priority is executed before the thread with a lower priority, and therefore, there is a possibility that the execution of the thread that has a lower priority is always postponed.

The Thread Class

The `java.lang.Thread` class is used to construct and access the individual threads in a multi-threaded application. You can create a multi-threaded application by using the `Thread` class or the `Runnable` interface.

The `Thread` class contains various methods that can be used to work with a thread, such as setting and checking the properties of a thread, causing a thread to wait, and being interrupted or destroyed. You can make the classes run in separate threads by extending the `Thread` class.

Some of the methods defined in the `Thread` class are:

- `int getPriority()`: Returns the priority of a thread.
- `boolean isAlive()`: Determines whether a thread is running.
- `static void sleep(long milliseconds)`: Causes the thread execution to pause for a period of time as specified by the value of `milliseconds`.
- `String getName()`: Returns the name of a thread.
- `void start()`: Starts a thread execution by calling the `run()` method.
- `static Thread currentThread()`: Returns a reference to the thread object that is currently executing.
- `boolean isAlive()`: Is used to check the existence of a thread. This method returns `true` if the thread is running, and returns `false` if the thread is new or gets terminated.
- `public final void join()`: Allows a thread to wait until the thread, on which it is called, terminates.
- `void interrupt()`: Is used to interrupt the execution of a thread.
- `static boolean interrupted()`: Is used to determine if the current thread has been interrupted by another thread.

You can use the following code to understand the usage of the methods in the `Thread` class:

```
class MainThreadDemo
{
  public static void main(String args[])
  {
    Thread t= Thread.currentThread();
    System.out.println(" The current thread: " + t);
    t.setName("MainThread");
    System.out.println(" The current thread after name change : "
    + t);
    System.out.println(" The current Thread is going to sleep for
    10 seconds");
    try
    {
   t.sleep(10000);
     }
    catch(InterruptedException e)
    {
     System.out.println("Main thread interrupted");
    }
   System.out.println(" After 10 seconds..........the current
      Thread is exiting now.");
    }
  }
```

Once the preceding code is executed, the following output is displayed:

```
The current thread: Thread[main,5,main]
The current thread after name change : Thread[MainThread,5,main]
The current Thread is going to sleep for 10 seconds
After 10 seconds..........the current Thread is exiting now.
```

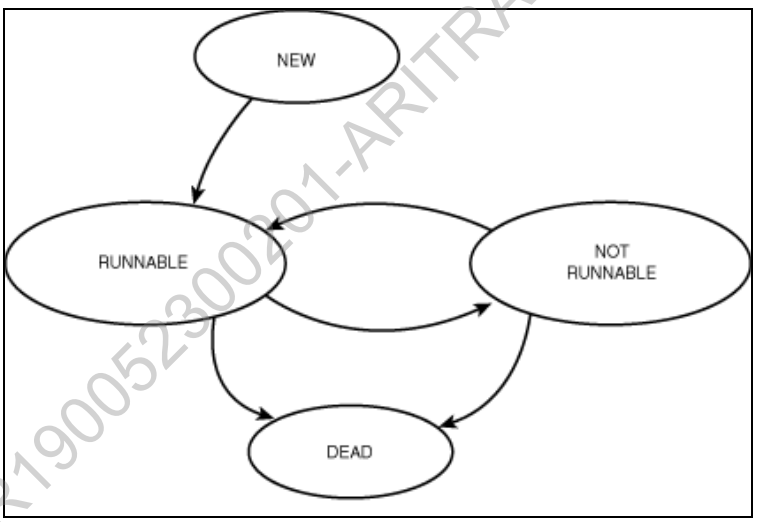
In the preceding code, the first thread to be executed is the main thread. It is created automatically when a Java program is executed. In the main program, a reference to the current thread is obtained by calling the `currentThread()` method and its reference is stored in the reference variable, `t`. The `setName()` method is called to set the name of the thread, and the information about the thread is displayed. The main thread is then made to sleep for 10 seconds by using the `sleep()` method, and after 10 seconds, the thread terminates. The `sleep()` method throws the `InterruptedException` exception whenever another thread interrupts the sleeping thread.

The Life Cycle of a Thread

The various states in the life cycle of a thread are:

- New
- Runnable
- Not Runnable
- Terminated or Dead

The following figure shows the life cycle of a thread.



The Life Cycle of a Thread

The New Thread State

When an instance of the `Thread` class is created, the thread enters the new thread state. The following code snippet shows how to instantiate the `Thread` class:

```
Thread newThread = new Thread(this, "threadName");
```

In the preceding code snippet, a new thread is created. This new thread is an empty object of the `Thread` class, and no system resources, such as memory, are allocated to it. You have to invoke the `start()` method to start the thread.

The following code snippet shows how to start a thread:

```
newThread.start();
```

The Runnable Thread State

When the `start()` method of a thread is invoked, the thread enters the runnable state. The `start()` method allocates the system resources to the thread, schedules the thread, and passes the control to its `run()` method.

A processor cannot execute more than one thread at a time. Therefore, the processor maintains a thread queue. When a thread starts, it is queued for the processor time, and it waits for its turn to execute. As a result, the state of the thread is said to be runnable and not running.

The Not Runnable Thread State

A thread is in the not runnable state if it is:

- **Sleeping**: A thread is put into the sleeping mode by calling the `sleep()` method. A sleeping thread continues with its execution after the specified time of sleep has elapsed.
- **Waiting**: A thread can be made to wait for some specified condition that needs to be satisfied by calling the `wait()` method of the `Object` class. The thread can be issued a notification of the status of the condition by invoking the `notify()` or `notifyAll()` method of the `Object` class.
- **Being blocked by another thread**: If blocked by an I/O operation, a thread enters the not runnable state.

The Dead Thread State

A thread enters the dead state once the statements in the `run()` method have executed. Assigning a `null` value to a thread object also changes the state of the thread to dead. The `isAlive()` method of the `Thread` class is used to determine whether a thread is alive or not. You cannot restart a dead thread. In addition, a thread can be killed by stopping its execution with the help of the `stop()` method.

Creating Threads

Consider a scenario of a jumbled up word game where you need to implement a timer in the game. The timer will be used to provide a duration of 60 seconds within which a player has to find the correct word corresponding to a jumbled up word. Further, the timer will be displayed on the game screen when a player is playing the game. When the timer reaches 0, the "Time Up!!!" message will be displayed to the player and the game will stop.

In order to implement the preceding functionalities, you can create a thread. This can be done by instantiating an object of the `Thread` class. You can create a thread in a Java application by using the following approaches:

- By extending the `Thread` class
- By implementing the `Runnable` interface

Further, you can also create multiple threads in an application by using the preceding approaches and set their priorities to determine their execution sequence in the JRE.

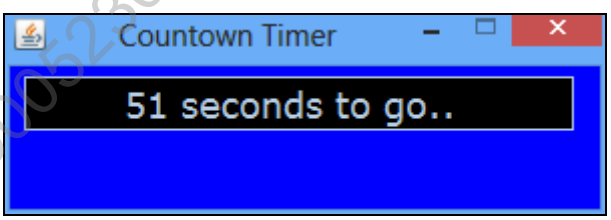
Creating a Thread by Extending the Thread Class

You can create threads by extending the `Thread` class. You need to specify the task to be performed by a thread in the overridden `run()` method. You can use the following code to create a thread to implement the timer by extending the `Thread` class:

```
import java.awt.Color;
import java.awt.Font;
import javax.swing.*;

public class CountdownTimer extends Thread {
    JTextField tf;
    JLabel l;
    JFrame fr;
    public void run()
    {
         buildGUI();
    }

    void display() {

        for (int i = 60; i >= 0; i--)
        {
            try {
                Thread.sleep(1000);
                String s = Integer.toString(i);

                tf.setText("        "+ s + " seconds to go..");
            } catch (Exception e) {
                System.out.println(e);
            }
```

```
            }
            JOptionPane.showMessageDialog(fr, "Time Up !!!!");
            tf.setText("");
            tf.setEnabled(false);
        }

        public void buildGUI() {
            fr = new JFrame("Countown Timer");
            JPanel p = new JPanel();
            l = new JLabel("");
            tf = new JTextField(15);
            tf.setEnabled(false);
            Font f = new Font("Verdana", 0, 18);
            tf.setFont(f);
            tf.setBackground(Color.BLACK);
            p.setBackground(Color.blue);
            fr.add(p);
            p.add(tf);
            p.add(l);
            fr.setVisible(true);
            fr.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
            fr.setSize(300, 100);
            fr.setResizable(false);
            display();
        }

        public static void main(String args[]) {
            CountdownTimer obj = new CountdownTimer();
            obj.start();
        }
    }
```

After executing the preceding code, the following output is displayed:



The Output

Note

The time in the preceding figure may vary.

In the preceding code, the `CountdownTimer` class extends the `Thread` class. A new instance of the `CountdownTimer` class is created in the `main()` method. The `start()` method begins the execution of a thread by calling the `run()` method that provides the implementation of the timer.

Creating a Thread by Implementing the Runnable Interface

Consider a scenario where you need to implement threads in a Java application and also extend another class to use its functionality, such as `JFrame`. Because Java does not support multiple inheritance, it provides the `Runnable` interface to solve this problem. The `Runnable` interface only consists of the `run()` method, which is executed when the thread is started.

When a program needs to inherit from a class other than the `Thread` class, you need to implement the `Runnable` interface to implement threads. The signature of the `run()` method is:

```
public void run()
```

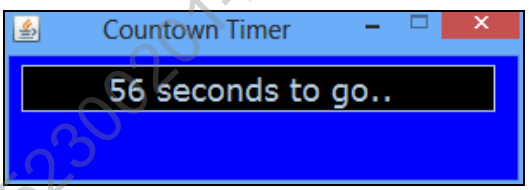
The `run()` method contains the code that the new thread will execute. When the `run()` method is called, another thread starts executing concurrently with the main thread in the program.

The class that implements the `Runnable` interface is used to create an instance of the `Thread` class. The new thread object starts by calling the `start()` method. You can use the following code to create a thread by implementing the `Runnable` interface for implementing the timer functionality:

```
import java.awt.Color;
import java.awt.Font;
import javax.swing.*;

public class CountdownTimer implements Runnable {
    JTextField tf;
    JLabel l;
    JFrame fr;
    public void run()
    {
         buildGUI();
    }

    void display() {

        for (int i = 60; i >= 0; i--)
        {
            try {
                Thread.sleep(1000);
                String s = Integer.toString(i);

                tf.setText("        "+ s + " seconds to go..");
            } catch (Exception e) {
                System.out.println(e);
            }

        }
        JOptionPane.showMessageDialog(fr, "Time Up !!!!");
        tf.setText("");
        tf.setEnabled(false);
    }
```

```
    public void buildGUI() {
        fr = new JFrame("Countown Timer");
        JPanel p = new JPanel();
        l = new JLabel("");
        tf = new JTextField(15);
        tf.setEnabled(false);
        Font f = new Font("Verdana", 0, 18);
        tf.setFont(f);
        tf.setBackground(Color.BLACK);
        p.setBackground(Color.blue);
        fr.add(p);
        p.add(tf);
        p.add(l);
        fr.setVisible(true);
        fr.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        fr.setSize(300, 100);
        fr.setResizable(false);
        display();
    }

    public static void main(String args[]) {
        CountdownTimer obj = new CountdownTimer();
        Thread CountdownThread = new Thread(obj);        //Initialize thread
        CountdownThread.start();
    }
}
```

Once the preceding code is executed, the following output is displayed:



The Output

Note

The time in the preceding figure may vary.

In the preceding code, the `CountdownTimer` class implements the `Runnable` interface. In the `main()` method, an object of the `CountdownTimer` class is created and the object is passed as a parameter to the constructor of the `Thread` class. The preceding object represents a runnable task. The `start()` method begins the execution of a thread by calling the `run()` method, which provides the implementation of the timer.

Creating Multiple Threads

Suppose you need to develop a car racing game where multiple objects, such as obstacles, need to move across the frame, simultaneously. For this, you need to create multiple threads where each thread represents an obstacle. You can create multiple threads in a program either by implementing the `Runnable` interface or extending the `Thread` class.

For the preceding scenario, you can use the following code to create multiple threads by using the `Thread` class:

```
import java.awt.Color;
import java.util.Random;
import javax.swing.*;
public class Race extends Thread{

    String ThreadName;
    JLabel l;
    JPanel l1,l2,l3;
    JFrame fr;

    public Race()
    {
    buildGUI();
    }
    public Race(String s)
    {
    super(s);
    }

    public void run()
    {

        if(Thread.currentThread().getName().equals("ObstacleA"))
        {
        runObstacleA();
        }
        if(Thread.currentThread().getName().equals("ObstacleB"))
        {
        runObstacleB();
        }
        if(Thread.currentThread().getName().equals("ObstacleC"))
        {
        runObstacleC();
        }

    }

    public void runObstacleA()
    {
        Random ran = new Random();
        int s = ran.nextInt(1000);
```

```
      for(int i=-10;i<400;i++)
      {

        l1.setBounds(i, s, 20, 20);
      try {
      Thread.sleep(5);

      }
      catch(Exception e)
      {
      System.out.println(e);
      }
   }
runObstacleC();
}

public void runObstacleB()
{
 Random ran = new Random();
      int r = ran.nextInt(180);

      for(int i=-10;i<400;i++)
      {
        l2.setBounds(i, r, 20, 20);
      try {
      Thread.sleep(11);

      }
      catch(Exception e)
      {
      System.out.println(e);
      }
   }
runObstacleA();
}

public void runObstacleC()
{
   Random ran = new Random();
      int m = ran.nextInt(10);

      for(int i=-10;i<400;i++)
      {
        l3.setBounds(i, m, 20, 20);
      try {
      Thread.sleep(10);

      }
      catch(Exception e)
      {
      System.out.println(e);
      }
   }
```

```
        runObstacleB();
        }
        public void buildGUI()
        {
            fr = new JFrame("Moving objects");
            fr.setVisible(true);
            fr.setSize(400,200);
            fr.setLayout(null);

            l = new JLabel("");
            l.setBounds(10,10,400,20);
            fr.add(l);

            l1 = new JPanel();
            l1.setSize(20, 20);
            l1.setBackground(Color.red);
            l1.setBounds(10,40,20,20);
            fr.add(l1);
            l2 = new JPanel();
            l2.setSize(20, 20);
            l2.setBackground(Color.blue);
            l2.setBounds(10,80,20,20);
            fr.add(l2);

            l3 = new JPanel();
            l3.setSize(20, 20);
            l3.setBackground(Color.black);
            l3.setBounds(10,120,20,20);
            fr.add(l3);

        }

        public static void main(String args[])
    {
                        Race obj = new Race();
                        Thread Obstacle1 = new Thread(obj);
                      Thread Obstacle2 = new Thread(obj);
                    Thread Obstacle3 = new Thread(obj);

                    Obstacle1.setName("ObstacleA");
                    Obstacle2.setName("ObstacleB");
                    Obstacle3.setName("ObstacleC");
                    Obstacle1.start();
                    Obstacle2.start();
                    Obstacle3.start();
        }
    }
```

In the preceding code, three thread references, `Obstacle1`, `Obstacle2`, and `Obstacle3` are created and the object `obj` of the `Race` class is passed as parameter. Then, `Obstacle1`, `Obstacle2`, and `Obstacle3` are given the names, `ObstacleA`, `ObstacleB`, and `ObstacleC`, respectively. These obstacles will appear at random positions.

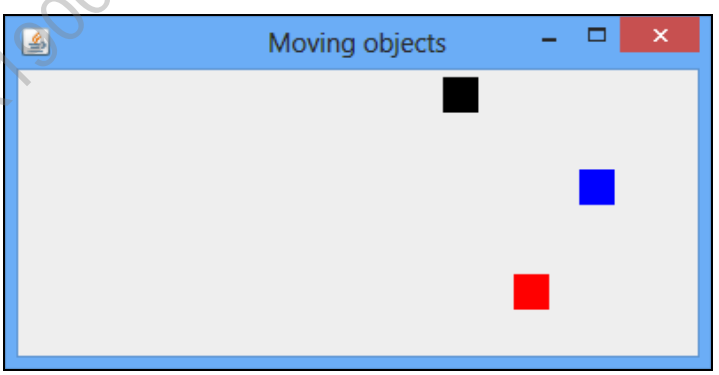
You can also use the following code to create multiple threads by using the `Runnable` interface:

```
import java.awt.Color;
import java.util.Random;
import javax.swing.*;

public class Race implements Runnable{

    String ThreadName;
    JLabel l;
    JPanel l1,l2,l3;
    JFrame fr;

    public Race()
    {
    buildGUI();
    }

    public void run()
    {
         if(Thread.currentThread().getName().equals("ObstacleA"))
         {
         runObstacleA();
         }
         if(Thread.currentThread().getName().equals("ObstacleB"))
         {
         runObstacleB();
         }
         if(Thread.currentThread().getName().equals("ObstacleC"))
         {
         runObstacleC();
         }

    }

    public void runObstacleA()
    {
         Random ran = new Random();
         int s = ran.nextInt(1000);
         for(int i=-10;i<400;i++)
         {

           l1.setBounds(i, s, 20, 20);
         try {
         Thread.sleep(5);

         }
         catch(Exception e)
         {
         System.out.println(e);
         }
       }
    runObstacleC();
    }
```

```
public void runObstacleB()
{
 Random ran = new Random();
     int r = ran.nextInt(180);

     for(int i=-10;i<400;i++)
     {
       l2.setBounds(i, r, 20, 20);
     try {
     Thread.sleep(11);

     }
     catch(Exception e)
     {
     System.out.println(e);
     }
  }
runObstacleA();
}

public void runObstacleC()
{
  Random ran = new Random();
     int m = ran.nextInt(10);

     for(int i=-10;i<400;i++)
     {
       l3.setBounds(i, m, 20, 20);
     try {
     Thread.sleep(10);

     }
     catch(Exception e)
     {
     System.out.println(e);
     }
  }
runObstacleB();
}

public void buildGUI()
{
    fr = new JFrame("Moving objects");
    fr.setVisible(true);
    fr.setSize(400,200);
    fr.setLayout(null);

    l = new JLabel("");
    l.setBounds(10,10,400,20);
    fr.add(l);

    l1 = new JPanel();
    l1.setSize(20, 20);
    l1.setBackground(Color.red);
```

```
            l1.setBounds(10,40,20,20);
            fr.add(l1);

            l2 = new JPanel();
            l2.setSize(20, 20);
            l2.setBackground(Color.blue);
            l2.setBounds(10,80,20,20);
            fr.add(l2);

            l3 = new JPanel();
            l3.setSize(20, 20);
            l3.setBackground(Color.black);
            l3.setBounds(10,120,20,20);
            fr.add(l3);

        }

        public static void main(String args[])
    {
                Race obj = new Race();
                Thread Obstacle1 = new Thread(obj);
                Thread Obstacle2 = new Thread(obj);
                Thread Obstacle3 = new Thread(obj);

    Obstacle1.setName("ObstacleA");
    Obstacle2.setName("ObstacleB");
    Obstacle3.setName("ObstacleC");
    Obstacle1.start();
    Obstacle2.start();
    Obstacle3.start();
        }
    }
```

In the preceding code, three threads, `ObstacleA`, `ObstacleB`, and `ObstacleC`, share the memory of the CPU. These obstacles will appear at random positions on the frame and move across the frame. Once the preceding code is executed, the following output is displayed:



The Output

Sometimes, in a multithreaded program, there may be a requirement to ensure that the execution of the main thread finishes after all the other threads have executed. For this, they will need to know whether a thread has finished its execution or else they can join the execution of a thread with the `main()` method. This can be determined by using the `isAlive()` method and the `join()` method.

Using the isAlive() Method

The `isAlive()` method is used to check the existence of a thread. You can use the `isAlive()` method to find the status of a thread. The signature of the `isAlive()` method is:

```
boolean isAlive()
```

In the preceding signature, the `isAlive()` method returns `true` if the thread is running, and returns `false` if the thread is new or gets terminated. The thread can be in a runnable or not runnable state if the `isAlive()` method returns `true`. The following code uses the `isAlive()` method:

```
class NewThreadClass implements Runnable
{
    Thread t;
    NewThreadClass()
    {
           t = new Thread(this,"ChildThread" );
           System.out.println("Thread created: " + t);
           t.start();
    }
    public void run()
    {
           try
           {
                  for(int i=1;i<=5;i++)
                  {
                         System.out.println(t + "loop :" + i);
                        Thread.sleep(100);
                  }
           }
           catch( InterruptedException obj)
           {
                  System.out.println("Thread :" + t + "interrupted");
           }
    }
}
class IsAliveDemo
{
     public static void main(String args[])
     {
           NewThreadClass obj = new NewThreadClass();
           System.out.println(obj.t  + "is alive ? : " +
             obj.t.isAlive());
    try
    {
                  for(int i=1;i<=5;i++)
                  {
                  System.out.println("Main Thread loop:" + i);
```

```
                    Thread.sleep(200);
                    }
          }
         catch(InterruptedException e)
                {
                System.out.println("Main thread is interrupted");}
                System.out.println(obj.t  + "is alive ? : " +
                  obj.t.isAlive());
                System.out.println("Main Thread is exiting");
         }
}
```

Once the preceding code is executed, the following output is displayed:

```
Thread created: Thread[ChildThread,5,main]
Thread[ChildThread,5,main]is alive ? : true
Main Thread loop:1
Thread[ChildThread,5,main]loop :1
Thread[ChildThread,5,main]loop :2
Main Thread loop:2
Thread[ChildThread,5,main]loop :3
Thread[ChildThread,5,main]loop :4
Thread[ChildThread,5,main]loop :5
Main Thread loop:3
Main Thread loop:4
Main Thread loop:5
Thread[ChildThread,5,]is alive ? : false
Main Thread is exiting
```

In the preceding code, the `isAlive()` method is called on the thread to check whether the thread is alive or dead.

Using the join() Method

The `join()` method allows a thread to wait until the thread, on which it is called, terminates. In addition, the `join()` method enables you to specify the maximum amount of time that you need to wait for the specified thread to terminate. The signature of the `join()` method is:

```
public final void join() throws InterruptedException
```

In the preceding signature, if another thread interrupts, the `join()` method throws the `InterruptedException` exception. The execution of a thread can be interrupted by another thread by using the `interrupt()` method of the `Thread` class. To determine if the current thread has been interrupted by another thread, the `Thread` class provides the `interrupted()` method.

Further, the `join()` method returns the control to the calling method when the specified thread dies. The following code uses the `join()` method:

```
class ChildThread implements Runnable
{
  Thread t;
  ChildThread()
  {
   t = new Thread(this,"ChildThread" );
```

```
    System.out.println("Thread created: " + t);
    t.start();
  }
  public void run()
  {
    try
    {
                for(int i=1;i<=5;i++)
          {
                System.out.println(t + "loop :" + i);
                Thread.sleep(500);
          }
    }
    catch( InterruptedException obj)
    {
          System.out.println("Thread :" + t + "interrupted");
    }
  }
}
public class JoinDemo
{
   public static void main(String args[])
    {
        ChildThread obj = new ChildThread();
              System.out.println(obj.t  + "is alive ? : " +
          obj.t.isAlive());
              try
          {
          System.out.println("Main thread waiting for child thread to
finish");
                obj.t.join();
          }
          catch(InterruptedException e)
          {
            System.out.println("Main thread is interrupted");
}
            System.out.println(obj.t  + "is alive ? : " +
            obj.t.isAlive());
            System.out.println("Main Thread is exiting");
    }
}
```

Once the preceding code is executed, the following output is displayed:

```
Thread created: Thread[ChildThread,5,main]
Thread[ChildThread,5,main]is alive ? : true
Main thread waiting for child thread to finish
Thread[ChildThread,5,main]loop :1
Thread[ChildThread,5,main]loop :2
Thread[ChildThread,5,main]loop :3
Thread[ChildThread,5,main]loop :4
Thread[ChildThread,5,main]loop :5
Thread[ChildThread,5,]is alive ? : false
```

In the preceding code, the `join()` method is called on the child thread and the main thread waits for the child thread to finish its execution.

Identifying the Thread Priorities

JRE executes threads based on their priority. Since a CPU is able to execute only one thread at a time, the threads that are ready for execution are scheduled in a queue to be executed by the processor. The threads are scheduled by JRE by using fixed-priority scheduling. Each thread has a priority that affects its position in the thread queue of the processor. A thread with a higher priority is scheduled for execution before the threads with a lower priority.

Defining Thread Priority

Thread priorities are integers in the range of 1 to 10 that specify the priority of one thread with respect to the priority of another thread. The execution of multiple threads on a single CPU in a specified order is called scheduling.

If the processor encounters another thread with a higher priority, the current thread is pushed back and the thread with the higher priority is executed. The next thread of a lower priority starts executing if a higher priority thread stops or becomes not runnable. A thread is pushed back in the queue by another thread if it is waiting for an I/O operation. A thread can also be pushed back in the queue when the time for which the `sleep()` method was called on another higher priority thread gets over.

Setting the Thread Priority

Once a thread is created, its priority is set by using the `setPriority()` method of the `Thread` class. The signature of the `setPriority()` method is:

```
public final void setPriority(int newPriority)
```

In the preceding signature, the `newPriority` parameter specifies the new priority setting for a thread. The priority levels should be within the range of two constants, `MIN_PRIORITY` and `MAX_PRIORITY`. The `MIN_PRIORITY` and `MAX_PRIORITY` constants have the values 1 and 10, respectively. The `setPriority()` method throws the `IllegalArgumentException` exception if the priority level is less than `MIN_PRIORITY` and greater than `MAX_PRIORITY`.

The thread can be set to a default priority by specifying the `NORM_PRIORITY` constant in the `setPriority()` method. `MAX_PRIORITY` is the highest priority that a thread can have. `MIN_PRIORITY` is the lowest priority a thread can have, and `NORM_PRIORITY` is the default priority set for a thread. You can use the following code to set the priorities of various threads:

```
class ChildThread implements Runnable
{
    Thread t;
    ChildThread(int p)
    {
      t = new Thread(this,"ChildThread" );
      t.setPriority(p);
      System.out.println("Thread created: " + t);
    }
```

```
   public void run()
  {
    try
          {
                for(int i=1;i<=5;i++)
          {
                      System.out.println(t + "loop :" + i);
                      Thread.sleep(500);
                      }
          }
          catch( InterruptedException obj)
          {
          System.out.println("Thread :" + t + "interrupted");}
          }
}
class PriorityDemo
{
  public static void main(String args[])
   {
   ChildThread obj1 = new ChildThread(Thread.NORM_PRIORITY - 2);
   ChildThread obj2 = new ChildThread(Thread.NORM_PRIORITY + 2);
          ChildThread obj3 = new ChildThread(Thread.NORM_PRIORITY + 3);

   //Starting the threads with different priority
   obj1.t.start();
          obj2.t.start();
          obj3.t.start();
          try
   {
     System.out.println("Main thread waiting for child thread to
       finish");
       obj1.t.join();
       obj2.t.join();
     obj3.t.join();
      }

   catch(InterruptedException e)
          {
          System.out.println("Main thread is interrupted");}
          System.out.println(obj1.t  + "is alive ? : " +
            obj1.t.isAlive());
                System.out.println(obj2.t  + "is alive ? : " +
            obj2.t.isAlive());
          System.out.println(obj3.t  + "is alive ? : " +
            obj3.t.isAlive());
                System.out.println("Main Thread is exiting");
     }
    }
```

Once the preceding code is executed, the following output is displayed:

```
Thread created: Thread[ChildThread,3,main]
Thread created: Thread[ChildThread,7,main]
Thread created: Thread[ChildThread,8,main]
Main thread waiting for child thread to finish
Thread[ChildThread,3,main]loop :1
Thread[ChildThread,7,main]loop :1
Thread[ChildThread,8,main]loop :1
Thread[ChildThread,7,main]loop :2
Thread[ChildThread,8,main]loop :2
Thread[ChildThread,3,main]loop :2
Thread[ChildThread,7,main]loop :3
Thread[ChildThread,8,main]loop :3
Thread[ChildThread,3,main]loop :3
Thread[ChildThread,7,main]loop :4
Thread[ChildThread,8,main]loop :4
Thread[ChildThread,3,main]loop :4
Thread[ChildThread,7,main]loop :5
Thread[ChildThread,8,main]loop :5
Thread[ChildThread,3,main]loop :5
Thread[ChildThread,3,]is alive ? : false
Thread[ChildThread,7,]is alive ? : false
Thread[ChildThread,8,]is alive ? : false
Main Thread is exiting
```

Activity 6.1: Implementing Threads in Java

Practice Questions

1. Identify the minimum value to set the thread priority.
   a. 5
   b. 10
   c. 1
   d. 15

2. Identify the method that is used to check the existence of a thread.
   a. `isAlive()`
   b. `sleep()`
   c. `syncrhonize()`
   d. `alive()`

3. Identify the method that returns the name of a thread.
   a. `name()`
   b. `getName()`
   c. `getThreadName()`
   d. `currentThreadName()`

4. Identify the method that is used to pause the execution of a thread for a period of time.
   a. `isAlive()`
   b. `sleep()`
   c. `notify()`
   d. `stop()`

5. Consider the following statements:
   Statement A: You cannot restart a dead thread.
   Statement B: When a thread is blocked by an I/O operation, it enters the not runnable state.
   Which one of the following options is correct based on the preceding statements?
   a. Both the statements are false.
   b. Both the statements are true.
   c. Statement A is true and Statement B is false.
   d. Statement B is true and Statement A is false.

Summary

In this chapter, you learned that:

- A thread is defined as the path of execution of a program. It is a sequence of instructions that is executed to define a unique flow of control.
- A program that creates two or more threads is called a multi-threaded program.
- The various advantages of multithreading are:
  - Improved performance
  - Minimized system resource usage
  - Program structure simplification
- The various disadvantages of multithreading are:
  - Race condition
  - Deadlock
  - Lock starvation
- The `java.lang.Thread` class is used to construct and access the individual threads in a multi-threaded application.
- The various states in the life cycle of a thread are:
  - New
  - Runnable
  - Not Runnable
  - Terminated or Dead
- You can create a thread in the following ways:
  - By extending the `Thread` class
  - By implementing the `Runnable` interface
- Thread priorities are the integers in the range of 1 to 10 that specify the priority of one thread with respect to the priority of another thread.
- You can set the thread priority after it is created by using the `setPriority()` method declared in the `Thread` class.

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Implementing Thread Synchronization and Concurrency

CHAPTER 7

You have learned how to create a multi-threaded Java application. In addition, you have learned that in a multi-threaded application, a resource can be accessed by multiple threads at a time. However, there may be situations when you need that at a time, only one thread should access the resource. For this, Java provides thread synchronization.

Moreover, to improve the performance of a multi-threaded application, Java supports concurrency. To implement concurrency, a program is split into tasks, which can be executed in parallel.

This chapter focuses on implementing thread synchronization and concurrency.

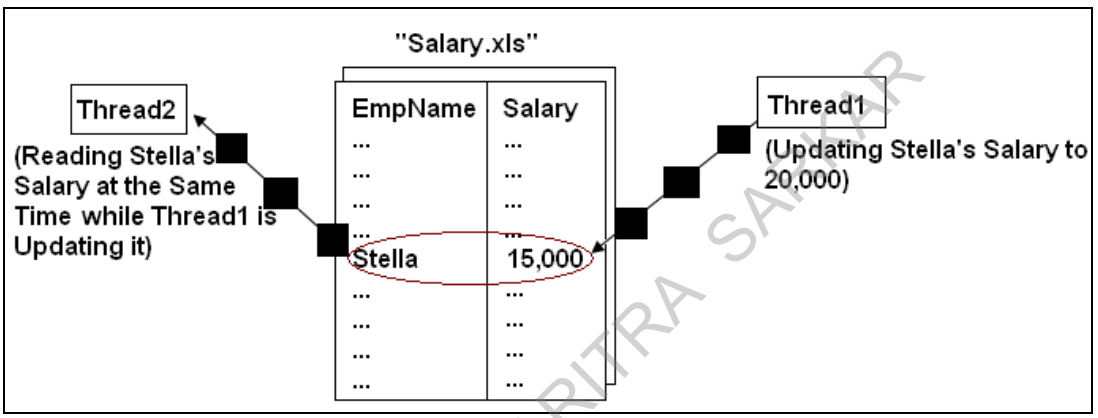
Objectives

In this chapter, you will learn to:

- Implement thread synchronization
- Implement concurrency

Implementing Thread Synchronization

In a multithreaded environment, when two threads need to share data, you must try to coordinate their activities to ensure that one thread does not change the data used by the other thread to avoid errors. For example, if you have two threads, one that reads a salary record from a file and another that tries to update the salary record at the same time, there is a possibility that the thread that is reading the salary record does not get the updated value. The following figure shows two threads accessing the data of a file at the same time.



The Two Threads Accessing Data at the Same Time

In the preceding figure, Thread1 is updating the salary of Stella to $20,000. At the same time, another thread, Thread2, is reading the salary of Stella before it is being updated. Therefore, the information read by Thread2 is faulty.

To avoid such situations, Java enables you to coordinate and manage the actions of multiple threads at a given time by using synchronized threads and implementing communication between threads.

Synchronizing Threads

Consider the scenario of a banking application that allows you to access a bank account and perform operations, such as deposit and withdraw amount. In addition, these operations can be performed by using mediums, such as the Internet and Automated Teller Machine (ATM). In such a scenario, there is a possibility that multiple operations are performed on an account simultaneously. This can lead to loss of data or inconsistency in data. Therefore, to avoid such issues, you need to implement a mechanism using which only a single operation can be performed on an account at a time. For this, you can apply thread synchronization.

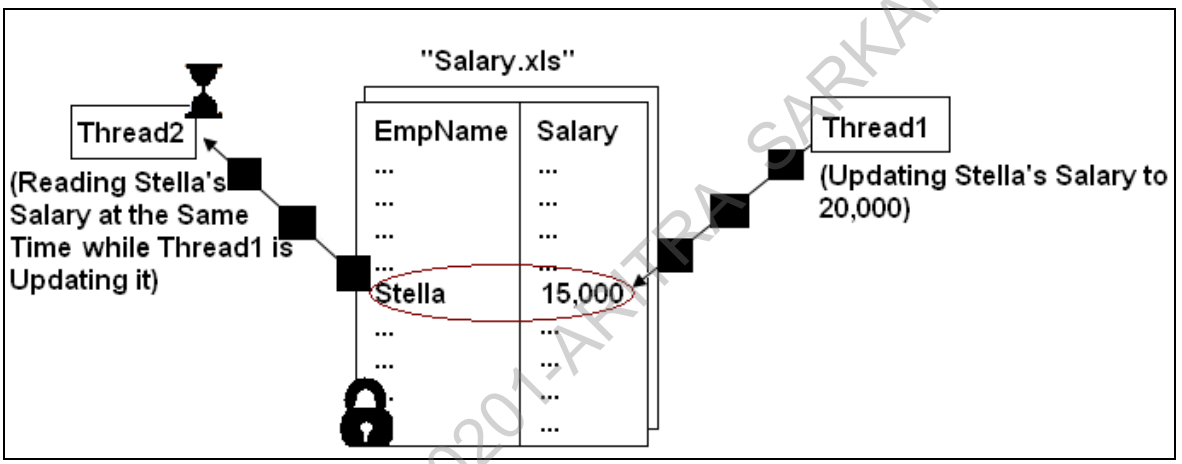
The synchronization of threads ensures that if two or more threads need to access a shared resource, then that resource is used by only one thread at a time. You can implement thread synchronization by using the following approaches:

- By using the synchronized methods
- By using the synchronized statement

The Synchronized Methods

You can synchronize a method by using the `synchronized` keyword. Synchronization is based on the concept of a monitor, which is an object used as a lock. All the Java objects have a monitor and only one thread can hold the monitor of an object at a given time. To enter an object's monitor, you need to call a synchronized method. The monitor controls the way in which synchronized methods access an object or class. When a thread acquires a lock, it is said to have entered the monitor. The monitor ensures that only one thread has access to the resources at any given time.

When a thread is within a synchronized method, all the other threads that try to call the method at the same time have to wait. During the execution of a synchronized method, the object is locked so that no other synchronized method can be invoked. The monitor is automatically released when the method completes its execution. The following figure shows an example of thread synchronization.



An Example of Thread Synchronization

In the preceding figure, Thread1 has a lock on the Salary.xls file, while updating the salary of Stella in the file. Thread2 wants to read the salary of Stella from the Salary.xls file and is waiting for Thread1 to release the lock on the file. While a thread is sleeping or waiting, it temporarily releases the lock it holds.

The following code snippet demonstrates how to implement synchronization for the preceding scenario by using a synchronized method:

```
class EmployeeDetails
{
// Details of the employee
}
class EmployeeSalaryTransaction
{
public synchronized int processSalary()
{
// Code to process the salary
}
}
```

In the preceding code snippet, the `processSalary()` method is a synchronized method. This method cannot be accessed by multiple threads at a time.

The Synchronized Statement

Synchronization among threads can also be achieved by using synchronized statements. The synchronized statement is used where the synchronization methods are not used in a class and you do not have access to the source code. Further, when a method contains only a small section of critical code for which synchronization is required, then you can use the synchronized statement instead of synchronizing the entire method. You can synchronize the access to an object of this class by placing the calls to the methods defined by it inside a `synchronized` block. The following code snippet shows how to use the `synchronized` block:

```
synchronized(obj)
{
/* statements to be synchronized*/
}
```

In the preceding code snippet, `obj` is a reference of the object to be synchronized.

The following code snippet demonstrates how to implement synchronization, in case of the banking application, by using the synchronized statement:

```
class EmployeeDetails
{
    // Details of the employee
}
class EmployeeSalaryTransaction
{
public int processSalary()
    {
            synchronized(obj)
        {
            // Code to process the salary
        }
    }
}
```

In the preceding code snippet, `obj` refers to an object of the `EmployeeDetails` class. The code to process the salary is specified within a `synchronized` block to ensure that it cannot be accessed by multiple threads at a time.

Implementing Inter-threaded Communication

Threads can communicate with each other. Multithreading eliminates the concept of polling by a mechanism known as interprocess communication. For example, there are two threads, thread1 and thread2. The data produced by thread1 is consumed by thread2. thread1 is the producer, and thread2 is the consumer. The consumer has to repeatedly check if the producer has produced data. This is a waste of CPU time as the consumer occupies the CPU time to check whether the producer is ready with data. A thread cannot proceed until the other thread has completed its task.

A thread may notify another thread that the task has been completed. This communication between threads is known as inter-threaded communication. The various methods used in inter-threaded communication are:

- `wait()`: Informs the current thread to leave its control over the monitor and wait until another thread calls the `notify()` method.
- `notify()`: Wakes up a single thread that is waiting for the monitor of the object being executed. If multiple threads are waiting, one of them is chosen randomly.
- `notifyAll()`: Wakes up all the threads that are waiting for the monitor of the object.

The following code shows the producer-consumer problem, but without inter-threaded communication:

```
class SynchronizedMethods
{
  int d;
    synchronized void getData()
    {
         System.out.println("Got data:" + d);

    }
    synchronized void putData(int d)
    {
         this.d = d;
         System.out.println("Put data:" + d);
   }
}
class Producer extends Thread
{
   SynchronizedMethods t;
   public Producer(SynchronizedMethods t)
   {
   this.t = t;
   }
   public void run()
   {
   int data =700;
   while(true)
        {
     System.out.println("Put Called by producer");
     t.putData(data++);
        }
   }
}
class Consumer extends Thread
{
   SynchronizedMethods t;
   public Consumer(SynchronizedMethods t)
   {
   this.t = t;
   }
   public void run()
   {
      while(true)
      {
   System.out.println("Get Called by consumer");
```

```
            t.getData();
        }
    }
}
public class ProducerConsumer
{
    public static void main(String args[])
    {
        SynchronizedMethods obj1 = new SynchronizedMethods();
        Producer p = new Producer(obj1);
        Consumer c = new Consumer(obj1);
        p.start();
        c.start();
    }
}
```

Once executed, the preceding code runs infinitely, as shown in the following output:

```
.
.
.
.
Put Called by producer
Put data:29670
Put Called by producer
Put data:29671
Put Called by producer
Put data:29672
Put Called by producer
Put data:29673
Put Called by producer
Put data:29674
Put Called by producer
Put data:29675
Put Called by producer
Put Called by producer
.
.
.
.
```

To avoid such errors, `wait()`, `notify()`, and `notifyAll()` methods are used. All the three methods can be called from within the synchronized methods.

The following code shows the inter-thread communication by using the `wait()` and `notify()` methods:

```
class SynchronizedMethods
{
int d;
boolean flag = false;
synchronized int getData()
{
if(!flag)
{
```

```
try
{
wait();
}

catch(InterruptedException e)
{
System.out.println(" Exception caught");
}
}
System.out.println("Got data:" + d);
flag=false;
notify();
return d;
}
synchronized void putData(int d)
{

if(flag)
{

try
{
wait();
}
catch(InterruptedException e)
{
System.out.println(" Exception caught");
}
}
this.d = d;
flag=true;
System.out.println("Put data with value:" + d);
notify();

}
}

class Producer implements Runnable
{
SynchronizedMethods t;
public Producer(SynchronizedMethods t)
{
this.t = t;
new Thread(this,"Producer").start();
System.out.println("Put Called by producer");
}
public void run()
{

int data =0;
while(true)
{
data=data+1;
```

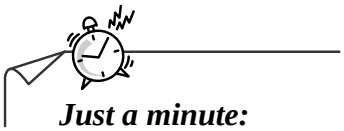
```
t.putData(data);
}
}
}
class Consumer implements Runnable
{
SynchronizedMethods t;
public Consumer(SynchronizedMethods t)
{
this.t = t;
new Thread(this,"Consumer").start();

System.out.println("Get Called by consumer");
}
public void run()
{

while(true)
{
t.getData();
}
}
}
public class InterThreadComm
{
public static void main(String args[])
{
SynchronizedMethods obj1 = new SynchronizedMethods();
Producer p = new Producer(obj1);
Consumer c = new Consumer(obj1);

}
}
```

Once the preceding code is executed, the following output is displayed:

```
Put Called by producer
Put data with value:1
Get Called by consumer
Got data:1
Put data with value:2
Got data:2
Put data with value:3
Got data:3
Put data with value:4
Got data:4
```

Note

The preceding output may vary.



Just a minute:

The _____ method is used to wake up all the threads that are waiting for the monitor of the object.

Answer:

`notifyAll()`

Activity 7.1: Implementing Synchronization

Implementing Concurrency

In a multithreaded environment, it is important to implement synchronization to eliminate the interference of threads and coordinate their activities. However, synchronization does not ensure that a multithreaded application is utilizing the system resources efficiently. There may be a situation in an application where multiple threads are waiting to obtain a lock on a synchronized method or code that is already locked. As a result, the efficiency of the application is hampered. Therefore, it is important to improve the efficiency of multithreaded applications and ensure that they are using the hardware resources of the system, such as the processor, to their potential. For this, the Java programming language supports concurrency.

Concurrency enables Java programmers to improve the efficiency and resource utilization of their applications by creating concurrent programs. Most computers today have more than a single processor to provide a faster performance. Therefore, by applying concurrency in Java applications, the program tasks can be managed to execute simultaneously by the systems that have multiple processors. You can achieve concurrency by dividing a program into multiple threads, where each thread has a separate task to perform. This minimizes the wastage of processing time and improves the execution speed of an application.

To implement concurrency, Java provides the `java.util.concurrent` package. This package contains the necessary classes and interfaces that can be used to implement the different ways to achieve concurrency and high performance in Java applications.

Implementing Atomic Variables and Locks

The `java.util.concurrent` package has the following sub packages to support concurrent programming:

- `java.util.concurrent.atomic`
- `java.util.concurrent.locks`

The java.util.concurrent.atomic Package

Consider a scenario of a multithreaded Java application that deals with updating and reading data, such as integer values stored in variables. You want to ensure that any change made to the data is updated immediately so that all the threads that access the variables get the latest value. You want to ensure that all the updates to variables are successfully accomplished and any change made is not lost due to problems, such as power outages. Moreover, you want that even in case of failures, such as starvation, the data is successfully updated. For this, you can use atomic variables. *Atomic variables* are the single variables on which operations, such as increment and decrement, are done in a single step. Such operations are known as atomic operations.

An *atomic operation* is an operation that is performed as a single unit. In addition, an atomic operation cannot be stopped in between by any other operations. Therefore, when multiple threads are working with an atomic variable to perform an operation, then that operation either happens completely in a single step or does not happen at all. The use of atomic variables improves performance as compared to synchronization and helps in avoiding inconsistency in data. The `java.util.concurrent.atomic` package provides many classes and methods that can be used to create atomic variables for performing atomic operations.

The following table lists the various classes of the `java.util.concurrent.atomic` package.

Class	***Description***
`AtomicBoolean`	*A `boolean` value that may be updated atomically.*
`AtomicInteger`	*An `int` value that may be updated atomically.*
`AtomicIntegerArray`	*An `int` array in which elements may be updated atomically.*
`AtomicLong`	*A `long` value that may be updated atomically.*
`AtomicLongArray`	*A `long` array in which elements may be updated atomically.*

The Classes of the java.util.concurrent.atomic Package

Consider the following code that demonstrates an atomic operation of an atomic integer variable:

```
import java.util.concurrent.atomic.AtomicInteger;
public class AtomicVariableDemo
{
    public static void main(String a[])
    {
        AtomicInteger value = new AtomicInteger(5);
        System.out.println("Intial value: " + value.get());
        value.getAndIncrement();
        System.out.println("After incrementing, the value: " + value.get());
        value.set(40);
        System.out.println("After setting, the value: " + value.get());
        value.getAndDecrement();
        System.out.println("After decrementing, the value: " + value.get());
        value.compareAndSet(39, 45);
        System.out.println("After updating, the value: " + value.get());
    }
}
```

In the preceding code, `AtomicInteger` named `value` is created with the value, `5`. The `get()` method of the `AtomicInteger` class is used to get the current value of the `value` variable. The `getAndIncrement()` method is then used to atomically increment the current value of the reference variable by `1`. Further, the `getAndDecrement()` method is used to atomically decrement the current value by `1`. The `compareAndSet()` method sets the value of the value variable to `45` if its value is `39`.

The java.util.concurrent.locks Package

You have learned how to implement synchronization in a multithreaded application. However, in an application that uses synchronized threads, if a thread is waiting to acquire a lock on an object and the lock is not available to be acquired, the thread may keep waiting to acquire the lock. This can result in a deadlock situation. Moreover, when there are multiple threads that are waiting to acquire a lock, it is not possible to determine the thread that will acquire the lock once it is available.

There is a possibility that the thread that has been waiting for the longest period of time never acquires the lock. In addition, when using synchronization, if an exception is raised while a thread is executing the critical section, then the lock may never be released. This can degrade the performance of an application. In order to overcome the preceding drawbacks, Java provides the `ReentrantLock` class in the `java.util.concurrent.locks` package. This class implements the `Lock` interface. A reentrant lock is used for mutual locking amongst threads. A reentrant lock can be acquired by the same thread any number of times.

In addition, this class provides useful methods that can be used to perform locking in a flexible and more productive manner by using a lock. A lock is a tool that is used for controlling access to a shared resource. The following table lists the constructors of the `ReentrantLock` class.

Constructor	***Description***
`ReentrantLock()`	*Is used to create an instance of the* `ReentrantLock` *class.*
`ReentrantLock(boolean fairness)`	*Is used to create an instance of the* `ReentrantLock` *class and set the fairness. The fairness option when set to true ensures that the lock is given to the longest waiting thread in the queue of waiting threads.*

The Constructors of the ReentrantLock Class

The following table lists some of the methods of the `ReentrantLock` class.

Method	***Description***
`void lock()`	*This method is used to acquire a lock. Further, this method cannot be interrupted.*
`boolean tryLock()`	*This method is used to acquire a lock only if it is available. If the lock is available, it returns with a* `true` *value, else it returns with a* `false` *value.*
`boolean tryLock(long time, TimeUnit unit)`	*This method is used to acquire a lock only if it is available in the specified time period. If the lock is available, it returns with a* `true` *value, else it returns with a* `false` *value.*
`void unlock()`	*This method is used to release a lock.*
`boolean isFair()`	*This method is used to return* `true` *if the fairness is set to* `true`*.*
`boolean isLocked()`	*This method is used to query if the lock is currently held by any thread.*

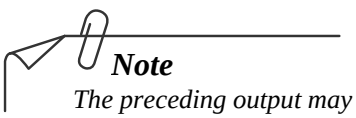
The Methods of the ReentrantLock Class

Consider the following code that shows how to implement a reentrant lock:

```
import java.util.concurrent.TimeUnit;
import java.util.concurrent.locks.Lock;
import java.util.concurrent.locks.ReentrantLock;
public class ReentrantLockImplementation implements Runnable {
    final Lock lock = new ReentrantLock();
    String name;
    Thread t;

    public void createThreads(String threadname) {
        name = threadname;
        t = new Thread(this, name);
        System.out.println("Creating New Thread: " + t.getName());
        t.start();
    }

    public static void main(String args[]) {
        ReentrantLockImplementation obj = new ReentrantLockImplementation();
        obj.createThreads("Thread 1");
        obj.createThreads("Thread 2");
        obj.createThreads("Thread 3");
    }

    public void run() {
        do {
            try {
                if (lock.tryLock(400, TimeUnit.MILLISECONDS)) {
                    try {
                     System.out.println(Thread.currentThread().getName()+"
acquired the lock. "
                                );
                     Thread.sleep(1000);
                    } finally {
                      lock.unlock();
                      System.out.println(Thread.currentThread().getName()+"
released the lock. "
                                );
                    }
                    break;
                }
                else
                {
                    System.out.println( Thread.currentThread().getName() + "
could not acquire the lock. Need to try for the lock again.");
                }
            }
            catch (InterruptedException e)
            {
                System.out.println(e);
            }
        } while (true);
    }
}
```

Once the preceding code is executed, the following output is displayed:

```
Creating New Thread: Thread 1
Creating New Thread: Thread 2
Creating New Thread: Thread 3
Thread 1 acquired the lock.
Thread 3 could not acquire the lock. Need to try for the lock again.
Thread 2 could not acquire the lock. Need to try for the lock again.
Thread 3 could not acquire the lock. Need to try for the lock again.
Thread 2 could not acquire the lock. Need to try for the lock again.
Thread 3 acquired the lock.
Thread 1 released the lock.
Thread 2 could not acquire the lock. Need to try for the lock again.
Thread 2 could not acquire the lock. Need to try for the lock again.
Thread 2 acquired the lock.
Thread 3 released the lock.
Thread 2 released the lock.
```



Note

The preceding output may change as the order of thread execution cannot be predicted.

In the preceding code, three threads namely `Thread 1`, `Thread 2`, and `Thread 3` are created. Also, a new `ReentrantLock` named `lock` is created. Then, on executing the `run()` method, a thread acquires a lock in the `try` block. Further, the `lock.tryLock(400, TimeUnit.MILLISECONDS)` statement is used to check if a lock is available in the time period of `400` milliseconds. If it is, then it is acquired, else, the threads need to try again for the lock. Once the task is complete, a thread releases the lock in the `finally` block, which ensures that the lock is finally released when a thread finishes its execution.

In addition, to implement separate locks for the read and writes operations, respectively, Java provides the `ReentrantReadWriteLock` class in the `java.util.concurrent.locks` package. This class allows you to have separate read and write versions of the same lock in such a way that only one thread is able to write and other threads are able to read at a given time. The `ReentrantReadWriteLock` class implements the `ReadWriteLock` interface.

The following table lists the constructors of the `ReentrantReadWriteLock` class.

Constructor	***Description***
`ReentrantReadWriteLock()`	*This method is used to create an instance of the `ReentrantReadWriteLock` class.*
`ReentrantReadWriteLock (boolean fairness)`	*This method is used to create an instance of the `ReentrantReadWriteLock` class and set the fairness. When the fairness option is set to `true`, it ensures that the lock is given to the longest waiting thread in the queue of waiting threads.*

The Constructors of the ReentrantReadWriteLock Class

The following table lists some of the methods of the `ReentrantReadWriteLock` class.

Method	***Description***
`Lock readLock()`	*This method is used to return the lock that is used for reading.*
`Lock writeLock()`	*This method is used to return the lock that is used for writing.*

The Methods of the ReentrantReadWriteLock Class

Consider the following code that shows how to implement `ReentrantReadWriteLock`:

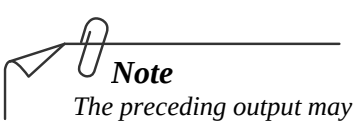
```
import java.util.Random;
import java.util.concurrent.locks.ReentrantReadWriteLock;

class ThreadLock extends Thread {

    private static final ReentrantReadWriteLock rwlock = new
ReentrantReadWriteLock();
    @Override
    public void run()
    {
        try {
            readData();
            sleep(2000);
            writeData();
        } catch (final Exception e)
        {
            System.out.println(e);
        }
    }
    public void readData()
    {
        try {
            rwlock.readLock().lock();
            System.out.println(Thread.currentThread().getName() + " is
reading and the value is 5");
        } finally {
            System.out.println(Thread.currentThread().getName() + " is
exiting after reading.");
            rwlock.readLock().unlock();
        }
    }

    public void writeData()
    {
        try {
            rwlock.writeLock().lock();
            Random rand = new Random();
            int n = rand.nextInt(50);
            System.out.println(Thread.currentThread().getName() + " has the
write lock and is writing.");
```

```
            System.out.println("The new value is: " + (5 + n));
        }
        finally
        {
            System.out.println(Thread.currentThread().getName() + " is
releasing the lock and exiting after writing.");
            rwlock.writeLock().unlock();
        }
    }
}

public class ReentrantLockTest {
    public static void main(final String[] args) throws Exception {
        ThreadLock obj = new ThreadLock();
        ThreadLock obj2 = new ThreadLock();
        obj.start();
        obj2.start();
    }
}
```

In the preceding code, a new `ReentrantReadWriteLock` lock named `rwlock` is created in the `ThreadLock` class that extends the `Thread` class. A method named `readData()` is created in the same class. When a thread begins executing this method, it obtains a read lock in the `try` block and releases it after performing its task in the `finally` block. The `readData()` method can be accessed by multiple threads for reading. Further, when a thread enters the `writeData()` method, it obtains a write lock and only the thread that has acquired the write lock can enter the critical section of the `writeData()` method. Finally, after performing the task, the thread releases the write lock so that it can be acquired by another waiting thread.

Once the preceding code is executed, the following output is displayed:

```
Thread-1 is reading and the value is 5
Thread-0 is reading and the value is 5
Thread-1 is exiting after reading.
Thread-0 is exiting after reading.
Thread-1 has the write lock and is writing.
The new value is: 9
Thread-1 is releasing the lock and exiting after writing.
Thread-0 has the write lock and is writing.
The new value is: 54
Thread-0 is releasing the lock and exiting after writing.
```



Note

The preceding output may change as the order of thread execution cannot be predicted.

Identifying Concurrency Synchronizers

Consider a scenario of a multithreaded application where you want to achieve coordination and concurrency amongst the threads of the application to minimize data inconsistency and errors. For example, you want the multiple threads of your application to exchange data or you want one or more threads to execute after a specific operation has been performed by another thread in the application. In such a scenario, you can use the synchronizer classes provided in the `java.util.concurrent` package. The following synchronizer classes are available:

- `Semaphore`
- `CountdownLatch`
- `CyclicBarrier`
- `Phaser`
- `Exchanger`

Semaphore

A *semaphore* is a lock with an internal counter. It is used to restrict access to shared resources by multiple threads at the same time. In addition, a semaphore can also be used to restrict the number of threads that can access a shared resource. Semaphores contain permits that should be acquired by a thread that wants access to a shared resource. Once the thread completes its work with the shared resource, the permit must be released by the thread. The `acquire()` and the `release()` methods are used to acquire and release a lock, respectively. If a permit is not available for a thread, then the requesting thread must wait until a permit is available to be acquired. As compared to a `synchronized` block, a semaphore provides the fairness capability. The fairness capability of the semaphore can be used to control the order in which the permits are given to requesting threads. When the fairness is set to `true`, then the semaphore gives permits in the order they were requested by the threads. For example, the thread that requested the permit first is given the permit. When fairness is set to `false`, a permit can be given to any thread that is waiting to acquire the permit. The use of a semaphore with fairness set to `true` helps in avoiding the starvation problem amongst threads in a concurrent environment.

CountDownLatch

This synchronizer class is useful in a situation where one or more threads need to wait until a set of operations or events is performed. Further, it is also useful when there is a need to synchronize multiple threads with the execution of a set of events or operations. When this synchronizer class is implemented, it is initialized with an integer number. This number is a counter value that represents the number of operations after which the waiting threads will start executing. This counter value can be retrieved by using the `getCount()` method. A thread that needs to wait for the completion of the preceding operations uses a method named `await()`. This method puts that thread to sleep until the operations are completed. When an operation completes, another method named `countDown()` is used to reduce the number of count by one. Finally, when the countdown reaches zero, all the sleeping threads are released.

CyclicBarrier

This synchronizer class is useful in a situation where multiple threads are required to wait at a predefined execution point that can be known as a barrier. For this, the `await()` method is used. This method is used by threads to wait for each other to reach the barrier. Once all the threads reach at the same barrier, then a task is performed. When this class is instantiated, you can specify the number of threads that will be participating to reach an execution point. The number of threads specified cannot vary over time. Additionally, during instantiation, the task to be performed, once the wait state is reached, can be specified. Then, the threads can complete their part and reach the same execution wait point. When the execution wait point is reached by all the threads, they can start working on the next part of their task.

Phaser

This synchronizer class is useful in a situation where independent threads need to work in phases or steps in order to complete a task. This class provides a similar functionality as provided by the `CyclicBarrier` class. However, by using this class, the number of threads that require to be synchronized by using a `Phaser` can be changed dynamically. To implement synchronization by using the `Phaser` class, an object of `Phaser` is created. A `Phaser` object can also be created with or without any threads. Further, the `register()` method is used to register each thread and the `arriveAndDeregister()` method is used to deregister a registered thread. The `bulkRegister()` method can also be used to register multiple threads in bulk. The `arriveAndAwaitAdvance()` method can be used to notify each thread to wait until the other threads reach the execution point. Once all the threads reach the execution point, the task to be executed can be specified by using the `onAdvance()` method.

Exchanger

This synchronizer class is useful in a situation where there is a need to perform synchronization and exchange of data between two concurrent running tasks. This class allows two threads to wait for a common point of exchange. If a thread reaches the point of exchange early, then it waits for the other thread to reach the common point of exchange. When both threads reach at this common point, they exchange the data shared by them. The method used to exchange data between threads is named `exchange()`. When a thread gets ready to exchange data, it invokes the `exchange()` method. If the other thread is not ready, the thread that invoked the exchange method is put to sleep till the time the other thread gets ready for data exchange.

Identifying Concurrency Collections

Consider a scenario where you need to create a concurrent program that implements collections to store and manage data. Some of the classes in the collection framework, such as `ArrayList`, cannot be used to work with multiple threads as the access to its data in a concurrent program cannot be controlled. For example, in a program, concurrent tasks on an unsynchronized collection of objects, such as `ArrayList`, by multiple threads can result in data inconsistency errors that can further affect the required functionality of the application. To avoid this, Java provides the concurrency collection classes in the `java.util.concurrent` package. The use of the collection classes improves the performance of a concurrent application and improves its scalability by allowing multiple threads to share a data collection.

Some of the concurrency collections available in the `java.util.concurrent` package that can be used for concurrent programming are:

- `ArrayBlockingQueue`: This is a blocking FIFO based queue in which the elements are maintained by using an array. In a FIFO queue, the new elements are inserted at the end of the queue and an element is removed from the head of the queue. You can specify the capacity of the number of elements that can be stored in the queue, while creating an instance of this class. Moreover, there is an upper bound on the number of elements that can be stored in the queue. This upper bound can be specified only at the time of instantiation and cannot be changed later. If a thread attempts to add an element to this queue when it is full, the thread will be blocked until an existing element is removed from the queue.
- `LinkedBlockingQueue`: This is a FIFO based queue where the maximum capacity of elements to be stored in the list can be specified. This queue is implemented by using a linked list that is a collection of nodes. If a thread attempts to add an element to this queue when it is full, the thread will be blocked until an existing element is removed from the queue. The throughput of this queue is higher than `ArrayBlockingQueue`.
- `PriorityBlockingQueue`: This is a blocking queue that orders elements based on their priority. If a thread attempts to add an element to this queue when it is full, the thread will be blocked until an existing element is removed from the queue. In addition, a thread is blocked when a thread attempts to remove an element and the queue is empty.
- `SynchronousQueue`: This is a blocking queue that blocks the request to add data to the queue until a request to retrieve the data from the queue is received, and vice versa. This queue does not have the capacity to store any data element.
- `DelayQueue`: This queue performs the ordering of its elements on the basis of the remaining time before which they can be eliminated from the queue. In such a queue, an object can only be retrieved from the queue when its delay time is zero. Only those objects that implement the `Delayed` interface can be used with this queue.
- `ConcurrentHashMap`: This class is an implementation of the `java.util.Map` interface that provides concurrency. This class is suitable for the multithreaded environment as it segments the internal table. This allows multiple threads to perform concurrent read operations. However, the lock can be applied only on the segment that needs to be updated. As compared to a `Hashtable` class, this class does not allow a key to have a null value. Also, the duplicate values are not allowed.
- `ConcurrentLinkedQueue`: This is a FIFO based queue that is based on linked nodes. This queue can be used for concurrent access. In this queue, the head of the queue represents the element that has been in the queue for the longest period. On the other hand, the tail represents the element that has been in the queue for the smallest time. This queue does not allow null elements to be entered in the queue.
- `ConcurrentSkipListMap`: This is a concurrent implementation of the `NavigableMap` interface. You can use an object of the `ConcurrentSkipListMap` map to store key-value pairs that are sorted according to the natural ordering of its keys, or by a comparator provided at map creation time, depending on which a constructor is used. In addition, the insertion, removal, update, and access operations in a `ConcurrentSkipListMap` collection can be safely executed concurrently by multiple threads.

- `ConcurrentSkipListSet`: Similar to `ConcurrentSkipListMap`, you can use the `ConcurrentSkipListSet` class to store the elements in a `Set` collection, where the addition insertion, removal, update, and access operations can be safely executed concurrently by multiple threads. The `ConcurrentSkipListSet` class implements the `NavigableSet` interface of the `java.util` package to enable navigation methods reporting closest matches for given search targets. In addition, similar to the `ConcurrentSkipListMap` class, the elements stored in a `ConcurrentSkipListSet` are sorted according to the natural ordering or by a comparator.
- `CopyOnWriteArrayList`: This is a thread-safe implementation of the `ArrayList` class. In this list, the operations, such as add and set, are performed by making a fresh copy of the array. Such a list is preferred as compared to a synchronized `ArrayList`, when the number of reads to be performed is more than the number of updates to be performed.
- `CopyOnWriteArraySet`: This class represents a set that uses `CopyOnWriteArrayList` for its operations. As it uses `CopyOnWriteArrayList` for its operations, it is thread-safe. Further, its use is preferred when the number of reads to be performed is more than the number of updates to be performed.

Practice Questions

1. Identify the keyword that is used to synchronize a method.
   a. `synchronize`
   b. `synchronized`
   c. `lock`
   d. `monitor`

2. Identify the method that is used to release a lock temporarily.
   a. `wait()`
   b. `release()`
   c. `synchronize()`
   d. `notify()`

3. Identify the method that is used to wake up a single thread that is waiting for the monitor of the object being executed.
   a. `wait()`
   b. `release()`
   c. `synchronize()`
   d. `notify()`

4. Identify the package that provides the classes and methods that can be used to create atomic variables for performing atomic operations.
   a. `java.util.concurrent.atomic`
   b. `java.util.atomic`
   c. `java.util.concurrent.atomicInteger`
   d. `java.util.concurrent.Integer`

Summary

In this chapter, you learned that:

- The synchronization of threads ensures that if two or more threads need to access a shared resource, then that resource is used by only one thread at a time.
- You can implement thread synchronization by using the following approaches:
  - By using the synchronized methods
  - By using the synchronized statement
- Synchronization is based on the concept of a monitor, which is an object used as a lock.
- When a thread is within a synchronized method, all the other threads that try to call the method at the same time have to wait.
- The synchronized statement is used where the synchronization methods are not used in a class and you do not have access to the source code.
- Multithreading eliminates the concept of polling by a mechanism known as interprocess communication.
- The various methods used in inter-threaded communication are:
  - `wait()`
  - `notify()`
  - `notifyAll()`
- Concurrency enables Java programmers to improve the efficiency and resource utilization of their applications by creating concurrent programs.
- To implement concurrency, Java provides the `java.util.concurrent` package.
- The `java.util.concurrent` package has the following sub packages to support concurrent programming:
  - `java.util.concurrent.atomic`
  - `java.util.concurrent.locks`
- Atomic variables are the single variables on which operations, such as increment and decrement, are done in a single step. Such operations are known as atomic operations.
- An atomic operation is an operation that is performed as a single unit.
- A reentrant lock is used for mutual locking amongst threads.
- In addition, to implement separate locks for the read and writes operations, respectively, Java provides the `ReentrantReadWriteLock` class in the `java.util.concurrent.locks` package.
- The following synchronizer classes are available:
  - `Semaphore`
  - `CountdownLatch`
  - `CyclicBarrier`
  - `Phaser`
  - `Exchanger`
- The use of the collection classes improves the performance of a concurrent application and improves its scalability by allowing multiple threads to share a data collection.

NIIT

Working with NIO Classes and Interfaces

CHAPTER 8

You have learned how to use traditional Input/Output (I/O) operations using the classes and interfaces in the `java.io` package. However, the traditional I/O operations lack useful features, such as file locking. Therefore, to overcome such issues and further improve the efficiency of Java applications, the New Input Output (NIO) Application Programming Interface (API) has been introduced to provide simpler and high-performance I/O operations.

This chapter focuses on NIO classes and interfaces. In addition, you will learn to read/write from/to a file efficiently using the NIO classes.

Objectives

In this chapter, you will learn to:

- Get familiar with NIO
- Perform the read and write operations on a file

Introducing NIO

In Java applications that perform I/O operations with files, you need to store data and retrieve the same from files and work with directories to access files. I/O operations utilize system resources, and therefore, must be performed efficiently to improve the performance of the applications and achieve the maximum processing productivity. The functionality offered by the `java.io` package for I/O operations had performance related issues, such as a thread performing a write operation was blocked until some data was transferred. Further, there were efficiency-related issues, such as there was no method to copy a file or directory. To overcome this and further simplify I/O operations, Java provides the `java.nio` package. The `java.nio` package provides sub packages and classes that are useful for improving the speed and performance of I/O operations.

In order to perform I/O operations on files and directories using the NIO API, you need to make use of the `Path` interface and the `Paths` class. In addition, to work with files and directories, you need to use the `Files` class. Further, NIO also provides support for monitoring a directory by implementing a watch service.

Using the Path Interface and the Paths Class

The `Path` interface is a component of the `java.nio.file` package, which provides support for identifying and working with files and directories. The `Path` interface is used to represent the path of a file or a directory that is located on a file system. A path comprises the name of the file, directory/directories, and drive. For example, `D:\Java\Sample\explorer.txt` represents the path where `explorer.txt` is the name of the file, `Java\Sample\` are the names of directories, and `D:\` is the name of the drive in the file system.

In order to work with a path, you need to create a reference of the `Path` interface. To obtain a `Path` reference, you need to use the `get()` method of the `Paths` helper class in the `java.nio.file` package. For example, to obtain a `Path` reference, you can use the following code snippet:

```
Path pathobject = Paths.get("D:\Java\Sample\explorer.txt");
```

In the preceding code snippet, a `Path` reference named `pathobject` is created. This reference represents the path, `D:\Java\Sample\explorer.txt`.

Further, the `Path` interface provides various methods, such as `getFileName()` to obtain information on paths of files or directories. The following table lists some of the most commonly used methods of the `Path` interface.

Method Name	***Description***	***Example***
`Path getFileName()`	*Returns the name of the file.*	*`Path pathobj = Paths.get("D:/NIODemo/Hello.java");`* *`System.out.println(pathobj.getFileName());`* *The output of the preceding code snippet is:* *`Hello.java`*

Method Name	Description	Example

`FileSystem getFileSystem()`	*Returns the name of the file system.*	`Path target=Paths.get("D:/Hello.java");`
		`System.out.println(target.getFileSystem());`
		The output of the preceding code snippet is:
		`sun.nio.fs.WindowsFileSystem@61316264`
		The digits after @ can vary.

`int getNameCount()`	*Returns the count of the number of elements that constitute the path, excluding the root drive letter, such as* `D:/`.	`Path target=Paths.get("D:/NIODemo/Hello.java");`
		`System.out.println(target.getNameCount());`
		The output of the preceding code snippet is:
		`2`

`Path getName(int index)`	*Returns the name element of the path as specified by the index value. An index value of* `0` *specifies the name that is closest to the root. An index value of count-1 specifies the name that is farthest from the root.*	`Path target=Paths.get("D:/NIODemo/Hello.java");`
		`System.out.println(target.getName(0));`
		The output of the preceding code snippet is:
		`NIODemo`

`Path getParent()`	*Returns the path where the file or directory is located. If a path is not specified or if the path does not have a parent, then* `null` *is returned.*	`Path target=Paths.get("D:/NIODemo/Hello.java");`
		`System.out.println(target.getParent());`
		The output of the preceding code snippet is:
		`D:\NIODemo`

`Path getRoot()`	*Returns the root drive component of the file, such as* `D:/`.	`Path target=Paths.get("D:/NIODemo/Hello.java");`
		`System.out.println(target.getRoot());`
		The output of the preceding code snippet is:
		`D:\`

Method Name	*Description*	*Example*

`boolean isAbsolute()`	*Returns* `true` *if the path is an absolute path. An absolute path represents the entire path hierarchy to locate a path.*	`Path target=Paths.get("D:/NIODemo/Hello.java");`
		`System.out.println(target.isAbsolute());`
		The output of the preceding code snippet is:
		`True`

`int compareTo(Path other)`	*Returns the result of a comparison of two paths. It returns* `0` *if the two paths are equal. It returns a value greater than* `0` *if the path specified is greater than the path specified as an argument. It returns a value that is less than* `0` *if the path specified is lesser than the path specified as an argument.*	`Path target=Paths.get("D:/NIODemo/Hello.java");`
		`Path comparePath=Paths.get("D:/NIODemo/Hello.java");`
		`Path compareNewPath=Paths.get("D:/NIODemo/NIO/Hello.java");`
		`System.out.println(comparePath.compareTo(target));`
		`System.out.println(compareNewPath.compareTo(target));`
		The output of the preceding code snippet is:
		`0`
		`6`

The Methods of the Path Interface

Note

In order to get the same output, as shown in the preceding table, ensure that the files used in the preceding code snippets are created at their respective locations.

Manipulating Files and Directories

Consider a scenario of a Java application where you need to perform various operations with the files and directories, such as searching a file, checking the existence of a file or directory or creating or deleting files or directories. To cater to the preceding requirement, you can use the methods of the `Files` class located in the `java.nio.file` package. In addition, in order to traverse files and directories, you need to use the `FileVisitor` interface.

Some of the file operations that can be performed using the `java.nio.file.Files` class are:

- Create a file or directory.
- Copy a file or directory.
- Move a file or directory.
- Check the existence of a file or directory.
- Delete a file or directory.
- Traverse a file tree.

Creating a File or Directory

To create a file, you need to use the `createFile()` method. The signature of the `createFile()` method is:

```
static Path createFile(Path path, FileAttribute<?>... attrs)
```

This method accepts a `Path` reference and creates a new file at the location specified by the `Path` reference variable. The `FileAttribute` reference is used to specify the attributes that define whether the file is being created for the purpose of reading and/or writing and/or executing. These attributes are file system dependent. Therefore, you need to utilize a file system-specific file permissions class and its helper class. For example, for a POSIX compliant file system, such as Unix, you can use the `PosixFilePermission` enum and the `PosixFilePermissions class, as shown in the following code snippet:`

```
Path target = Paths.get("\Backup\MyStuff.txt");
Set<PosixFilePermission> perms
    = PosixFilePermissions.fromString("rw-rw-rw-");
FileAttribute<Set<PosixFilePermission>> attr
    = PosixFilePermissions.asFileAttribute(perms);
Files.createFile(target, attr);
```

In the preceding code, `rw-rw-rw-` specifies the permissions, which are applied on the `MyStuff.txt` file when it is created. If the file location does not exist, the `java.nio.file.NoSuchFileException` exception is thrown. In addition, if you try to create a file that already exists at the same location, the `java.nio.file.FileAlreadyExistsException` exception is raised. However, it is not mandatory to specify the file attributes. The following code snippet shows how to create a file without specifying the file attributes:

```
Path pathObject = Paths.get("D:/NIODemo.java");
Files.createFile(pathObject);
```

In the preceding code snippet, `pathObject` is a reference variable of the `Path` interface. `pathObject` stores the path returned by the `get()` method. The `pathObject` reference variable is passed to the `createFile()` method. The `createFile()` method creates a file named `NIODemo.java` in the D:\ drive.

Similarly, to create a directory, the `createDirectory()` method is used. The signature of the `createDirectory()` method is:

```
static path createDirectory(Path dir, FileAttribute<?>... attrs)
```

This method accepts a `Path` reference and creates a new directory at the location specified by the path reference variable. The `FileAttribute` reference is used to specify the attributes that define whether the directory is being created for the purpose of reading and/or writing and/or executing. It is not mandatory to specify the preceding file attributes. If you try to create a directory that already exists at the same location, then `java.nio.file.FileAlreadyExistsException` is raised.

The following code snippet shows how to create a directory without specifying the file attributes:

```
Path pathObject = Paths.get("D:/NIO");
Files.createDirectory(pathObject);
```

In the preceding code snippet, `pathObject` is a reference variable of the `Path` interface. `pathObject` stores the path returned by the `get()` method. The `pathObject` reference variable is passed to the `createDirectory()` method. The `createDirectory()` method creates a directory named `NIO` in the D:\ drive.

If there is a requirement to create a single level or multiple levels of directories, such as D:\User1\Java\Programs, you need to specify the relevant path and use the `createDirectories(Path dir, FileAttribute<?>... attrs)` method. This method does not throw an exception if the directories already exist.

The following code snippet shows how to create multiple directories by using the `createDirectories()` method:

```
Path newdir = Paths.get("D:/User1/Java/Programs");
        try
          {
                    Files.createDirectories(newdir);
          }
       catch (IOException e)
          {
            System.err.println(e);
          }
```

In the preceding code snippet, the `createDirectories()` method creates the directories as specified by the path reference, `newdir`.

Copying a File or Directory

To copy a file, you need to use the `copy()` method of the `Files` class. The signature of the `copy()` method is:

```
public static Path copy(Path source, Path target, CopyOption... options)
```

This method accepts two `Path` references for the source file to be copied and the target file to be created as a copy of the source file, respectively. Further, `CopyOption... options` is used to specify one or more copy options that determine how the copy process should be done. It is not mandatory to specify the copy options. These options are listed under the `StandardCopyOption` and `LinkOption` enums.

The following table lists the commonly used copy options that can be specified with the `copy()` method.

Enum	***Option***	***Description***
StandardCopyOption	*REPLACE_EXISTING*	*This option allows performing the copy process even if the specified target file already exists. Otherwise, if this option is not specified and the target file already exists, an exception is thrown.*
StandardCopyOption	*COPY_ATTRIBUTES*	*This option allows copying the file attributes associated with the source file to the target file. The file attributes define the characteristics of a file, such as its creation time and last modification time.*
LinkOption	*NOFOLLOW_LINKS*	*This option allows you to specify that the symbolic links should not be followed to their actual target file. A symbolic link is a file that contains a reference to another target file or directory.*

The Copy Options Used with the copy() Method

The following code snippet shows how to copy a file:

```
import java.io.IOException;
import java.nio.file.Files;
import java.nio.file.Path;
import java.nio.file.Paths;
import static java.nio.file.StandardCopyOption.*;

public class NIOdemo
{
    public static void main(String[] args)
    {
        Path source = Paths.get("D:/Hello.java");
        Path target=Paths.get("D:/NIODemo/Hello.java");
        try
        {
            Files.copy(source, target, REPLACE_EXISTING, COPY_ATTRIBUTES);
        }
        catch(IOException e)
        {
        System.out.println(e);
        }
    }
}
```

In the preceding code snippet, the source file to be copied is specified by the `source` path reference and the file to be created with the copy process is specified at the `D:/NIODemo/Hello.java` location. If the source file to be copied does not exist, the `java.nio.file.NoSuchFileException` exception is thrown. In addition, if a target file already exists and the `REPLACE_EXISTING` option is not specified, the `FileAlreadyExistsException` exception is thrown.

Moving a File or Directory

To move an existing file or directory, you can use the `move()` method specified in the `Files` class. The signature of the `move()` method is:

```
public static Path move(Path source, Path target, CopyOption... options)
```

This method accepts two `Path` references for the source file or directory to be moved and the target file or directory to which the source file or directory should be moved, respectively. However, if the specified target file already exists, the move process fails. Further, `CopyOption... options` is used to specify one or more copy options that determine how the copy or move process should be done. These options are listed under the `StandardCopyOption` enum. The following table lists the copy options that can be specified with the `move()` method.

Option	***Description***
REPLACE_EXISTING	*This option allows performing the move process even if the specified target file already exists.*
ATOMIC_MOVE	*This option is used to perform the move process as an atomic operation. An atomic operation cannot be interrupted in between.*

The Copy Options Used with the move() Method

The following code shows how to move an existing file to another location:

```
import java.io.IOException;
import java.nio.file.Files;
import java.nio.file.Path;
import java.nio.file.Paths;
import static java.nio.file.StandardCopyOption.*;

public class NIOdemo {
    public static void main(String[] args)
{
        Path source = Paths.get("D:/NIODemo/Hello.java");
        Path target=Paths.get("D:/NIODemo/NIO/Hello.java");
        try
        {
                    Files.move(source, target, REPLACE_EXISTING);
        }
```

```
        catch(IOException e)
        {
        System.out.println(e);
        }
}
}
```

In the preceding code, the `Hello.java` file located in the `D:/NIODemo` directory is moved to the D:\NIODemo\NIO directory. If the source file does not exist at the specified location or if an invalid target location is specified, the `NoSuchFileException` exception is thrown.

The following code snippet shows how to move an existing directory to another directory:

```
Path source = Paths.get("D:/Pictures");
        Path target=Paths.get("D:/NIODemo/NIO/NewEmptyDirectory");
        Files.move(source, target, REPLACE_EXISTING);
```

When the preceding code snippet is executed, the contents specified at the D:\Pictures path will be moved to the `NewEmptyDirectory` directory. While moving a directory, it is important to ensure that the target directory is empty. Otherwise, the `DirectoryNotEmptyException` exception is thrown. If the target directory location does not exist at the specified location, the `NoSuchFileException` exception is thrown.

Checking the Existence of a File or Directory

To check whether a file or directory exists or it does not exist, you can use the `exists()` and `notExists()` methods of the `Files` class, respectively. The `exists()` method tests whether a file exists. The signature of the `exists()` method is:

```
public static boolean exists(Path path, LinkOption... options)
```

This method accepts a path reference, `path`, which is to be verified for its existence. Further, the link options are used to specify how the symbolic links should be handled if the path represents a symbolic link. This method returns `true` if the file or directory exists. Otherwise, it returns `false`. The following code snippet shows how to use the `exists()` method:

```
Path target=Paths.get("D:/NIODemo/NIO/NewEmptyDirectory");
Boolean pathExists = Files.exists(target, LinkOption.NOFOLLOW_LINKS);
System.out.println(pathExists);
```

In the preceding code snippet, the path, `D:/NIODemo/NIO/NewEmptyDirectory`, is verified for its existence.

Similarly, you can use the `notExists()` method to check if a file or directory does not exist. This method returns `true` if a file or directory does not exist. Otherwise, it returns `false`. The following code snippet shows how to use the `notExists()` method:

```
Path target=Paths.get("D:/NIODemo/NIO/NewEmptyDirectory");
Boolean pathExists = Files.notExists(target, LinkOption.NOFOLLOW_LINKS);
System.out.println(pathExists);
```

In the preceding code snippet, the path, `D:/NIODemo/NIO/NewEmptyDirectory`, is verified for its non existence.

Deleting a File or Directory

To delete a file, directory, or symbolic link, you can use either the `delete(Path path)` method or the `deleteIfExists(Path path)` method. The signature of the `delete()` method is:

```
public static void delete(Path path)
```

The preceding method accepts a `Path` reference that specifies the path to be deleted. The following exceptions may be thrown by this method:

- `NoSuchFileException`: Is thrown if the path does not exist.
- `DirectoryNotEmptyException`: Is thrown if the path specifies a directory that is not empty.
- `IOException`: Is thrown in case of an I/O error.
- `SecurityException`: Is thrown if the permission to delete the file is denied.

The following code snippet shows how to delete a file:

```
Path target=Paths.get("D:/NIODemo/NIO/Hello.java");
Files.delete(target);
```

Once the preceding code snippet is executed, the Hello.java file that is located in the D:\NIODemo\NIO directory is deleted.

Similarly, you can use the `deleteIfExists()` method for deleting a file or a directory. The signature of this method is:

```
public static boolean deleteIfExists(Path path)
```

The preceding method accepts a path reference that specifies the path to be deleted. However, this method does not throw an exception in case the specified path does not exist. In such a case, it returns a boolean value, `false`. The following code snippet shows how to use the `deleteIfExists()` method:

```
Path target=Paths.get("D:/NIODemo/NIO/Hello.java");
System.out.println(Files.deleteIfExists(target));
```

Once the preceding code snippet is executed, the `Hello.java` file located in the `D:\NIODemo\NIO` directory is deleted if it exists and the appropriate boolean value is printed.

Traversing a File Tree

Consider a scenario where you need to create a Java application that should traverse all the folders and files located in your directory structure to perform an operation such as, create, find, or delete a file. Further, you may want to recursively copy the contents of a directory to another directory. To meet the preceding requirements, you can use the `FileVisitor` interface provided by NIO. This interface is located in the `java.nio.file` package.

The `FileVisitor` interface provides support to traverse a file tree recursively. It also allows you to gain control over the traversal process and perform operations during the traversal process. In order to perform operations during the traversal process, this interface provides some methods.

You need to override the following methods to perform operations during the traversal process:

- `FileVisitResult preVisitDirectory()`: This method is used with a directory and is invoked before visiting its contents.
- `FileVisitResult postVisitDirectory()`: This method is used with a directory and is invoked after all its contents are visited.
- `FileVisitResult visitFile()`: This method is used with a file and is invoked when that file is visited during the traversal process.
- `FileVisitResult visitFileFailed()`: This method is used with a file and is invoked when the file to visit cannot be accessed.

Each of the preceding methods returns a value of the type, the `FileVisitResult` enum. This value is used to determine how to proceed with the traversal process. Some of the constant values in the `FileVisitResult` enum are:

- `CONTINUE`: Is used to indicate that the traversal must continue.
- `SKIP_SUBTREE`: Is used to indicate that the traversal must proceed without visiting the contents inside the directory.
- `TERMINATE`: Is used to indicate that the traversal must terminate.

Further, to start the traversal process, you need to use the `walkFileTree()` method in the `Files` class. This method accepts the path from where the traversal process needs to be started and the instance of the class that implements the `FileVisitor` interface. The signature of this method is:

```
public static Path walkFileTree(Path startpoint, FileVisitor<? super Path>
visitor)
```

In the preceding signature, `startpoint` represents the path reference from which the traversal should begin. `FileVisitor<? super Path> visitor` represents the instance of the class that implements the `FileVisitor` interface.

The following code shows how to implement the file tree traversal process by using the `FileVisitor` interface:

```
import java.io.IOException;
import java.nio.file.FileVisitResult;
import java.nio.file.FileVisitor;
import java.nio.file.Files;
import java.nio.file.Path;
import java.nio.file.Paths;
import java.nio.file.attribute.BasicFileAttributes;

class MyFileVisitor implements FileVisitor<Path> {

    public FileVisitResult postVisitDirectory(Path dir, IOException e) throws
IOException {
        System.out.println("Just Visited " + dir);
        return FileVisitResult.CONTINUE;
    }
```

```
    public FileVisitResult preVisitDirectory(Path dir, BasicFileAttributes
attrs) throws IOException {

        System.out.println("About to visit " + dir);
                return FileVisitResult.CONTINUE;

    }

        public FileVisitResult visitFile(Path file, BasicFileAttributes
attrs) throws IOException {

        System.out.println("Currently visiting "+file);
        System.out.println("Is this file a directory: "+
Files.isDirectory(file));
        System.out.println("Checking done..!!");
        return FileVisitResult.CONTINUE;

    }

        public FileVisitResult visitFileFailed(Path file, IOException e)
throws IOException {
        System.err.println(e.getMessage());
        return FileVisitResult.CONTINUE;
    }
}
public class NIODemo
{
    public static void main(String a[]) throws IOException
    {
Path listDir = Paths.get("D:/NIO");
MyFileVisitor obj = new MyFileVisitor();
Files.walkFileTree(listDir, obj);
    }
}
```

The output of the preceding code is:

```
About to visit D:\NIO
About to visit D:\NIO\Hello
Just Visited D:\NIO\Hello
Currently visiting D:\NIO\Hello.txt
Is this file a directory: false
Checking done..!!
Just Visited D:\NIO
```

Note

The preceding output may vary based on contents of the `D:/NIO` directory.

In the preceding code, `listDir` represents a path reference from where the traversal should begin. Then, the `walkFileTree()` method is used to start the traversal from the path specified by `listDir` by using the `obj` instance of the `MyFileVisitor` class. In this class, the methods of the `FileVisitor` interface are overridden. The `postVisitDirectory()` method prints the `Just Visited` message and the file or directory name. The `preVisitDirectory()` method prints the `About to visit` message and the file or directory name. The `visitFile()` method prints the name of the currently visited file and also checks if the visited path is a directory by using the `Files.isDirectory()` method. Further, the `visitFileFailed()` method is used to print a message if the file visit fails.

However, there can be a requirement where you do not need to provide an implementation for all the methods of the `FileVisitor` interface, but only for a few methods. In such a case, you can extend the `SimpleFileVisitor` class. For example, when there is a requirement to print only the names of the files in a file tree when they are visited. The `SimpleFileVisitor` class implements the `FileVisitor` interface, and therefore, its methods can be overridden depending upon the requirement of the application.

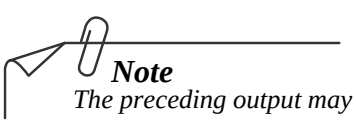
Consider a scenario, where you need to perform a pattern match to obtain a list and count of filenames that match a pattern, such as *.java. Therefore, to match a filename with the pattern name, you can use the `PathMatcher` class. The following code demonstrates how to search for all the .java files in the D:\ drive of your computer:

```
import java.io.IOException;
import java.nio.file.FileSystem;
import java.nio.file.FileSystems;
import java.nio.file.FileVisitOption;
import java.nio.file.FileVisitResult;
import java.nio.file.FileVisitor;
import java.nio.file.Files;
import java.nio.file.Path;
import java.nio.file.PathMatcher;
import java.nio.file.Paths;
import java.nio.file.attribute.BasicFileAttributes;
import java.util.EnumSet;

class SearchDemo implements FileVisitor {

    private final PathMatcher matcher;
    int counter = 0;

    public SearchDemo(String pattern) {
        FileSystem fs=FileSystems.getDefault();
        matcher = fs.getPathMatcher("glob:" + pattern);
    }

    void search(Path file) throws IOException {
        Path name = file.getFileName();

        if (name != null && matcher.matches(name)) {

            System.out.println("Searched file located: " + name + " in " +
file.getParent().toAbsolutePath());
            counter++;
        }
    }
```

```
    public FileVisitResult postVisitDirectory(Object dir, IOException exc)
            throws IOException {

        return FileVisitResult.CONTINUE;
    }


    public FileVisitResult preVisitDirectory(Object dir, BasicFileAttributes
attrs)
            throws IOException {
        return FileVisitResult.CONTINUE;
    }


    public FileVisitResult visitFile(Object file, BasicFileAttributes attrs)
            throws IOException {
        search((Path) file);
        return FileVisitResult.CONTINUE;
    }


    public FileVisitResult visitFileFailed(Object file, IOException exc)
            throws IOException {
        return FileVisitResult.CONTINUE;
    }
}

class MainClass {

    public static void main(String[] args) throws IOException {
        String pattern = "*.java";
        Path fileTree = Paths.get("D:/");
        SearchDemo walk = new SearchDemo(pattern);
        EnumSet opts = EnumSet.of(FileVisitOption.FOLLOW_LINKS);
        Files.walkFileTree(fileTree, opts, Integer.MAX_VALUE, walk);
        System.out.println("Total files found: " + walk.counter);
    }
}
```

The output of the preceding code is:

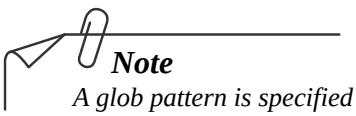
```
Searched file located: Hello.java in D:\NIODemo
Searched file located: NIODemo - Copy.java in D:\
Searched file located: NIODemo.java in D:\
Searched file located: ThreadOutput.java in D:\PPS
Searched file located: Puzzle.java in D:\
Total files found: 5
```



Note

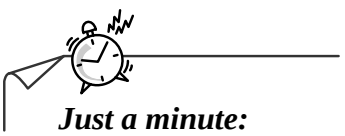
The preceding output may vary.

In the preceding code, in the `main()` method, the pattern is specified as `*.java`. In the constructor, the `getPathMatcher()` method is used. This method is used to create a `PathMatcher` for performing match operations on paths. The `FileSystems.getDefault()` method returns an object of the `FileSystem` class. The `getPathMatcher()` method is used to obtain the object of the `PathMatcher` class. This method is accepting a glob pattern, such as glob:*.java. Further, the `matches()` method is used to compare the name of the browsed files against the glob pattern. By using the `counter` variable, the total files that match the pattern are displayed inside the `main()` method.



Note

A glob pattern is specified as a string and used to specify a pattern to be matched against strings, such as file names.



Just a minute:

The_____ constant of the `FileVisitResult` enum is used to indicate that the traversal must end.

Answer:

`TERMINATE`

Activity 8.1: Performing File Operations Using NIO

Practice Questions

1. Which one of the following methods of the `Paths` helper class is used to obtain a file path reference?
   a. `get()`
   b. `getFileName()`
   c. `getName()`
   d. `getRoot()`

2. Identify the method of the `Path` interface that returns the name of the file system.
   a. `getFileName()`
   b. `getFileSystem()`
   c. `FileSystem()`
   d. `getParent()`

3. Identify the method of the `Path` interface that is used to identify if a path represents the entire path hierarchy.
   a. `getFileName()`
   b. `getFileSystem()`
   c. `getRoot()`
   d. `isAbsolute()`

4. Identify the exception that is thrown when you try to create a directory that already exists at the specified location while using the `createDirectory()` method.
   a. `FileAlreadyExistsException`
   b. `DirectoryNotEmptyException`
   c. `NoSuchFileException`
   d. `IOException`

5. Identify the interface that provides support for traversing a file structure recursively.
   a. `FileVisitor`
   b. `FileReader`
   c. `Watchable`
   d. `Path`

Summary

In this chapter, you learned that:

- The `java.nio` package provides sub packages and classes that are useful for improving the speed and performance of I/O operations.
- The `Path` interface is a component of the `java.nio.file` package, which provides support for identifying and working with files and directories.
- Some of the file operations that can be performed using the `java.nio.file.Files` class are:
  - Create a file or directory
  - Copy a file or directory
  - Move a file or directory
  - Check the existence of a file or directory
  - Delete a file or directory
  - Traverse a file tree
- To create a file, you need to use the `createFile()` method.
- To copy a file, you need to use the `copy()` method of the `Files` class.
- To move an existing file or directory, you can use the `move()` method specified in the `Files` class.
- To check whether a file or directory exists or it does not exist, you can use the `exists()` and `notExists()` methods of the `Files` class, respectively.
- To delete a file, directory, or symbolic link, you can use either the `delete(Path path)` method or the `deleteIfExists(Path path)` method.
- The `FileVisitor` interface provides support to traverse a file tree recursively.
- A buffer is a storage area in the memory that can be used for writing or reading data.

NIIT

Introduction to JDBC

CHAPTER 9

Java Database Connectivity (JDBC) is an API that executes SQL statements. It consists of a set of classes and interfaces written in the Java programming language. The interface is easy to connect to any database using JDBC. The combination of Java and JDBC makes the process of disseminating information easy and economical.

This chapter introduces the JDBC architecture. It gives an overview of the different types of drivers supported by JDBC. It elaborates the methods to establish the connection with SQL Server using the Type 4 JDBC driver.

Objectives

In this chapter, you will learn to:

- Identify the layers in the JDBC architecture
- Identify the types of JDBC drivers
- Use JDBC API
- Access result sets

Identifying the Layers in the JDBC Architecture

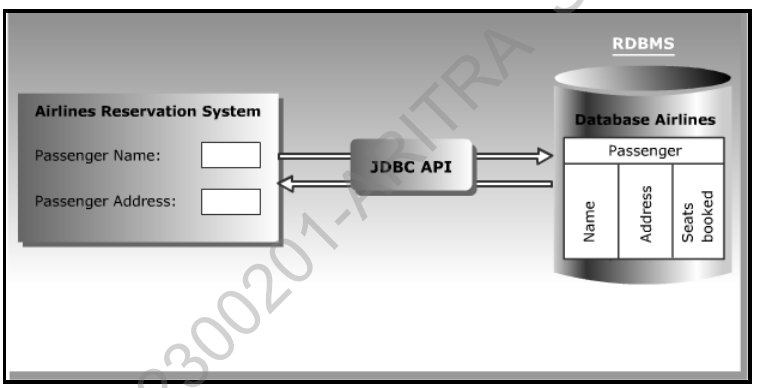
Consider a scenario where you have to develop an application for an airlines company that maintains a record of daily transactions. You install SQL Server as an RDBMS, design the airlines database, and ask the airlines personnel to use it. Will the database alone be of any use to the airlines personnel?

The answer will be negative. The task of updating data in the SQL Server database by using SQL statements alone will be a tedious process. An application will need to be developed that is user friendly and provides the options to retrieve, add, and modify data at the touch of a key to a client.

Therefore, you need to develop an application that communicates with a database to perform the following tasks:

- Store and update the data in the database.
- Retrieve the data stored in the database and present it to users in a proper format.

The following figure shows Airline Reservation System developed in Java that interacts with the Airlines database using the JDBC API.



The Database Connectivity Using the JDBC API

JDBC Architecture

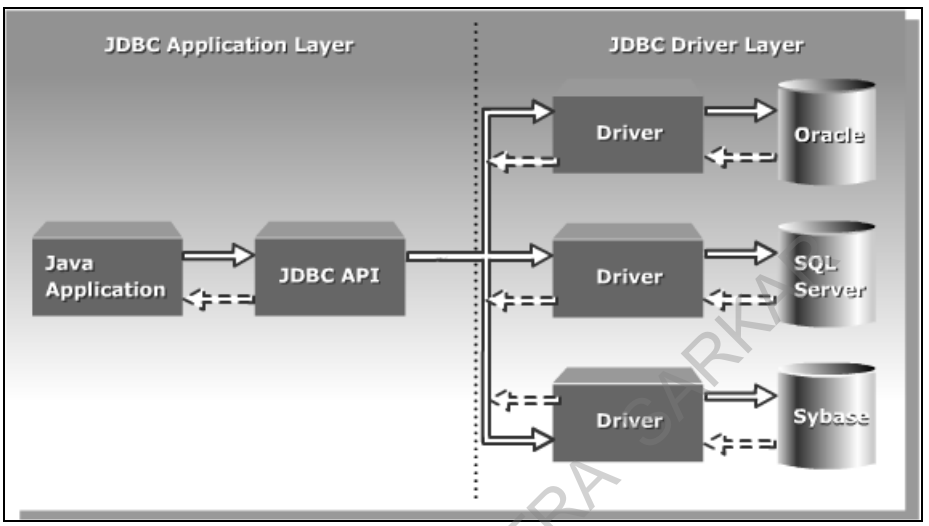
Java applications cannot communicate directly with a database to submit data and retrieve the results of queries. This is because a database can interpret only SQL statements and not Java language statements. Therefore, you need a mechanism to translate Java statements into SQL statements. The JDBC architecture provides the mechanism for this kind of translation.

The JDBC architecture has the following two layers:

- **JDBC application layer**: Signifies a Java application that uses the JDBC API to interact with the JDBC drivers. A JDBC driver is the software that a Java application uses to access a database.
- **JDBC driver layer**: Acts as an interface between a Java application and a database. This layer contains a driver, such as the SQL Server driver or the Oracle driver, which enables connectivity to a database. A driver sends the request of a Java application to the database. Once this request is processed, the

database sends the response back to the driver. The response is then translated and sent to the JDBC API by the driver. The JDBC API finally forwards this response to the Java application.

The following figure shows the JDBC architecture.



The JDBC Architecture

Just a minute:

Identify the two layers of the JDBC architecture.

Answer:

The two layers of the JDBC architecture are:

1. *JDBC application layer*
2. *JDBC driver layer*

Identifying the Types of JDBC Drivers

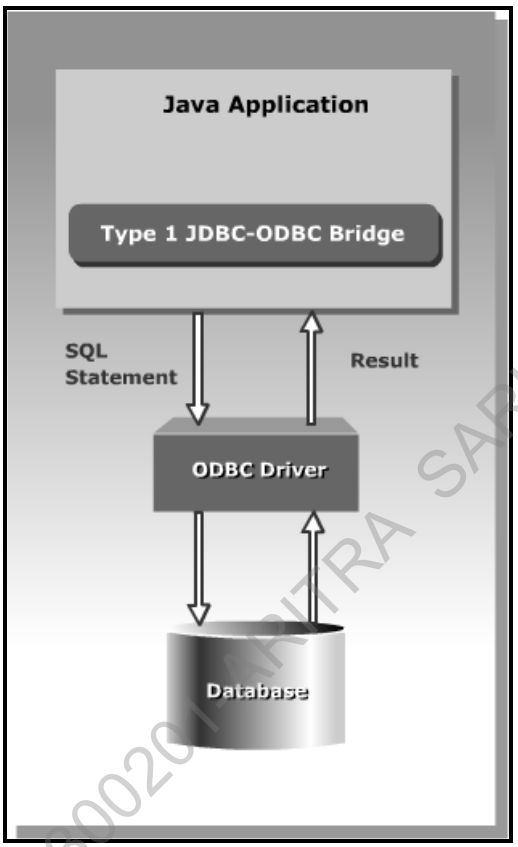
While developing JDBC applications, you need to use JDBC drivers to convert queries into a form that a particular database can interpret. The JDBC driver also retrieves the result of SQL statements and converts the result into equivalent JDBC API class objects that the Java application uses. Because the JDBC driver only takes care of the interactions with the database, any change made to the database does not affect the application. JDBC supports the following types of drivers:

- JDBC-ODBC Bridge driver
- Native-API driver
- Network Protocol driver
- Native Protocol driver

The JDBC-ODBC Bridge Driver

The JDBC-ODBC Bridge driver is called the Type 1 driver. The JDBC-ODBC Bridge driver converts the JDBC method calls into the *Open Database Connectivity (ODBC)* function calls. ODBC is an open standard API to communicate with databases. The JDBC-ODBC Bridge driver enables a Java application to use any database that supports the ODBC driver. A Java application cannot interact directly with the ODBC driver. Therefore, the application uses the JDBC-ODBC Bridge driver that works as an interface between the application and the ODBC driver. To use the JDBC-ODBC Bridge driver, you need to have the ODBC driver installed on the client computer. The JDBC-ODBC Bridge driver is usually used in standalone applications.

The following figure shows how the JDBC-ODBC Bridge driver works.

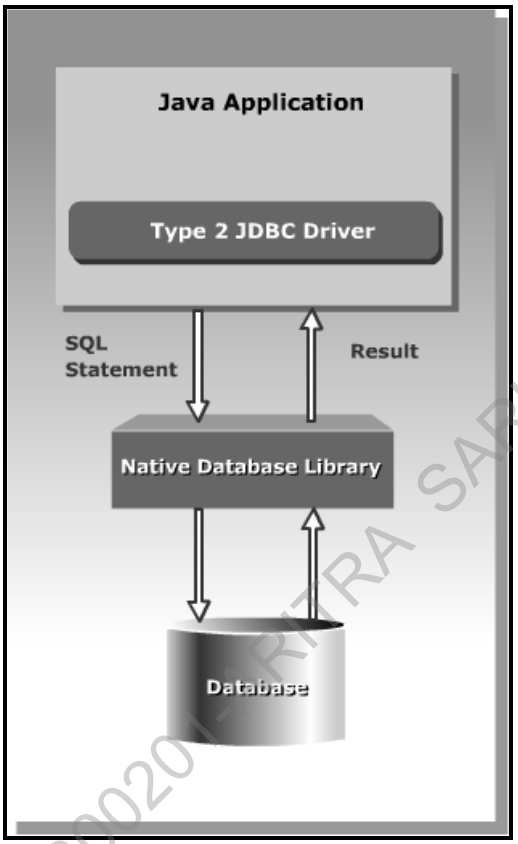


The JDBC-ODBC Bridge Driver

The Native-API Driver

The Native-API driver is called the Type 2 driver. It uses the local native libraries provided by the database vendors to access databases. The JDBC driver maps the JDBC calls to the native method calls, which are passed to the local native *Call Level Interface (CLI)*. This interface consists of functions written in the C language to access databases. To use the Type 2 driver, CLI needs to be loaded on the client computer. Unlike the JDBC-ODBC Bridge driver, the Native-API driver does not have an ODBC intermediate layer. As a result, this driver has a better performance than the JDBC-ODBC Bridge driver and is usually used for network-based applications.

The following figure shows how the Native-API driver works.

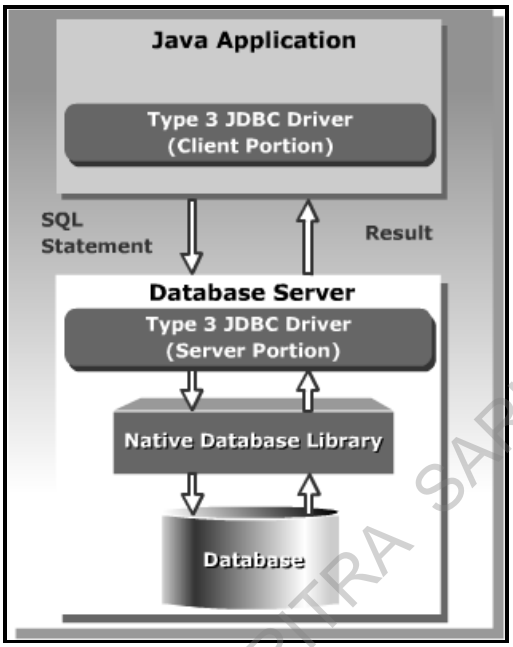


The Native-API Driver

The Network Protocol Driver

The Network Protocol driver is called the Type 3 driver. The Network Protocol driver consists of client and server portions. The client portion contains pure Java functions, and the server portion contains Java and native methods. The Java application sends JDBC calls to the Network Protocol driver client portion, which in turn, translates JDBC calls into database calls. The database calls are sent to the server portion of the Network Protocol driver that forwards the request to the database. When you use the Network Protocol driver, CLI native libraries are loaded on the server.

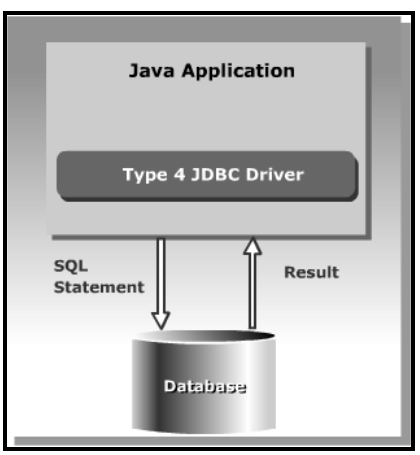
The following figure shows how the Network Protocol driver works.



The Network Protocol Driver

The Native Protocol Driver

The Native Protocol driver is called the Type 4 driver. It is a Java driver that interacts with the database directly using a vendor-specific network protocol. Unlike the other JDBC drivers, you do not require to install any vendor-specific libraries to use the Type 4 driver. Each database has the specific Type 4 drivers. The following figure shows how the Native Protocol driver works.



The Native Protocol Driver

Using JDBC API

You need to use database drivers and the JDBC API while developing a Java application to retrieve or store data in a database. The JDBC API classes and interfaces are available in the `java.sql` and `javax.sql` packages. The classes and interfaces perform a number of tasks, such as establish and close a connection with a database, send a request to a database, retrieve data from a database, and update data in a database. The classes and interfaces that are commonly used in the JDBC API are:

- The `DriverManager` class: Loads the driver for a database.
- The `Driver` interface: Represents a database driver. All JDBC driver classes must implement the `Driver` interface.
- The `Connection` interface: Enables you to establish a connection between a Java application and a database.
- The `Statement` interface: Enables you to execute SQL statements.
- The `ResultSet` interface: Represents the information retrieved from a database.
- The `SQLException` class: Provides information about exceptions that occur while interacting with databases.

To query a database and display the result using Java applications, you need to:

- Load a driver.
- Connect to a database.
- Create and execute JDBC statements.
- Handle SQL exceptions.

Loading a Driver

The first step to develop a JDBC application is to load and register the required driver using the driver manager. You can load and register a driver by:

- Using the `forName()` method of the `java.lang.Class` class.
- Using the `registerDriver()` static method of the `DriverManager` class.

Using the forName() Method

The `forName()` method loads the JDBC driver and registers the driver. The following signature is used to load a JDBC driver to access a database:

```
Class.forName("package.sub-package.sub-package.DriverClassName");
```

You can load the JDBC-Type 4 driver for SQL Server using the following code snippet:

```
Class.forName("com.microsoft.sqlserver.jdbc.SQLServerDriver");
```

Using the registerDriver() Method

You can create an instance of the JDBC driver and pass the reference to the `registerDriver()` method. The following syntax is used for creating an instance of the JDBC driver:

```
Driver d=new <driver name>;
```

You can use the following code snippet to create an instance of the JDBC driver:

```
Driver d = new com.microsoft.sqlserver.jdbc.SQLServerDriver();
```

Once you have created the `Driver` object, call the `registerDriver()` method to register the driver, as shown in the following code snippet:

```
DriverManager.registerDriver(d);
```

Connecting to a Database

You need to create an object of the `Connection` interface to establish a connection of the Java application with a database. You can create multiple `Connection` objects in a Java application to access and retrieve data from multiple databases. The `DriverManager` class provides the `getConnection()` method to create a `Connection` object. The `getConnection()` method is an overloaded method that has the following three forms:

- `public static Connection getConnection(String url)`
- `public static Connection getConnection(String url, Properties info)`
- `public static Connection getConnection(String url, String user, String password)`

The `getConnection (String url)`method accepts the JDBC URL of the database, which you need to access as a parameter. You can use the following code snippet to connect a database using the `getConnection()` method with a single parameter:

```
String url =
"jdbc:sqlserver://localhost;user=MyUserName;password=password@123";
Connection con = DriverManager.getConnection(url);
```

The following signature is used for a JDBC Uniform Resource Location (URL) that is passed as a parameter to the `getConnection()` method:

```
<protocol>:<subprotocol>:<subname>
```

A JDBC URL has the following three components:

- `protocol`: Indicates the name of the protocol that is used to access a database. In JDBC, the name of the access protocol is always `jdbc`.
- `subprotocol`: Indicates the vendor of Relational Database Management System (RDBMS). For example, if you use the JDBC-Type 4 driver of SQL Server to access its database, the name of `subprotocol` will be `sqlserver`.
- `subname`: Indicates *Data Source Information* that contains the database information, such as the location of the database server, name of a database, user name, and password, to access a database server.

Creating and Executing JDBC Statements

Once a connection is created, you need to write the JDBC statements that are to be executed. You need to create a `Statement` object to send requests to a database and retrieve results from the same. The `Connection` object provides the `createStatement()` method to create a `Statement` object. You can use the following code snippet to create a `Statement` object:

```
Connection
con=DriverManager.getConnection("jdbc:sqlserver://sqlserver01;databaseName=Li
brary;user=user1;password=password#1234");
Statement stmt = con.createStatement();
```

You can use static SQL statements to send requests to a database. The SQL statements that do not contain runtime parameters are called static SQL statements. You can send SQL statements to a database using the `Statement` object. The `Statement` interface contains the following methods to send the static SQL statements to a database:

- `ResultSet executeQuery(String str)`: Executes an SQL statement and returns a single object of the type, `ResultSet`. This object provides you the methods to access data from a result set. The `executeQuery()` method should be used when you need to retrieve data from a database table using the `SELECT` statement. The syntax to use the `executeQuery()` method is:

  ```
  Statement stmt = con.createStatement();
  ResultSet rs = stmt.executeQuery(<SQL statement>);
  ```

  In the preceding syntax, `stmt` is a reference to the object of the `Statement` interface. The `executeQuery()` method executes an SQL statement, and the result retrieved from a database is stored in `rs` that is the `ResultSet` object.

- `int executeUpdate(String str)`: Executes SQL statements and returns the number of rows that are affected after processing the SQL statement. When you need to modify data in a database table using the Data Manipulation Language (DML) statements, `INSERT`, `DELETE`, and `UPDATE`, you can use the `executeUpdate()` method. The syntax to use the `executeUpdate()` method is:

  ```
  Statement stmt = con.createStatement();
  int count = stmt.executeUpdate(<SQL statement>);
  ```

  In the preceding syntax, the `executeUpdate()` method executes an SQL statement and the number of rows affected in a database is stored in `count` that is the `int` type variable.

- `boolean execute(String str)`: Executes an SQL statement and returns a `boolean` value. You can use this method when you are dynamically executing an unknown SQL string. The `execute()` method returns `true` if the result of the SQL statement is an object of `ResultSet` else it returns `false`. The syntax to use the `execute()` method is:

  ```
  Statement stmt = con.createStatement();
  stmt.execute(<SQL statement>);
  ```

  You can use the DML statements, `INSERT`, `UPDATE`, and `DELETE`, in Java applications to modify the data stored in the database tables. You can also use the Data Definition Language (DDL) statements, `CREATE`, `ALTER`, and `DROP`, in Java applications to define or change the structure of database objects.

Querying a Table

Using the `SELECT` statement, you can retrieve data from a table. The `SELECT` statement is executed using the `executeQuery()` method and returns the output in the form of a `ResultSet` object. You can use the following code snippet to retrieve data from the `Authors` table:

```
String str = "SELECT * FROM Authors";
Statement stmt = con.createStatement();
ResultSet rs = stmt.executeQuery(str);
```

In the preceding code snippet, `str` contains the `SELECT` statement that retrieves data from the `Authors` table. The result is stored in the `ResultSet` object, `rs`.

When you need to retrieve selected rows from a table, the condition to retrieve the rows is specified in the `WHERE` clause of the `SELECT` statement. You can use the following code snippet to retrieve selected rows from the `Authors` table:

```
String str = "SELECT * FROM Authors WHERE city='London'";
Statement stmt = con.createStatement();
ResultSet rs = stmt.executeQuery(str);
```

In the preceding code snippet, the `executeQuery()` method retrieves the details from the `Authors` table for a particular city.

Inserting Rows in a Table

You can add rows to an existing table using the `INSERT` statement. The `executeUpdate()` method enables you to add rows in a table. You can use the following code snippet to insert a row in the `Authors` table:

```
String str = " INSERT INTO Authors (au_id, au_name, phone, address, city,
state, zip) VALUES ('A004', 'Ringer Albert', '8018260752', ' 67 Seventh Av.
', 'Salt Lake City', 'UT', '100000078')";
Statement stmt = con.createStatement();
int count = stmt.executeUpdate(str);
```

In the preceding code snippet, `str` contains the `INSERT` statement that you need to send to a database. The object of the `Statement` interface, `stmt`, executes the `INSERT` statement using the `executeUpdate()` method and returns the number of rows inserted in the table to the `count` variable.

Updating Rows in a Table

You can modify the existing information in a table using the `UPDATE` statement. You can use the following code snippet to modify a row in the `Authors` table:

```
String str = "UPDATE Authors SET address='10932 Second Av.' where au_id=
'A001'";
Statement stmt = con.createStatement();
int count = stmt.executeUpdate(str);
```

In the preceding code snippet, `str` contains the `UPDATE` statement that you need to send to a database. The `Statement` object executes this statement using the `executeUpdate()` method and returns the number of rows modified in the table to the `count` variable.

Deleting Rows from a Table

You can delete the existing information from a table using the `DELETE` statement. You can use the following code snippet to delete a row from the `Authors` table:

```
String str = "DELETE FROM Authors WHERE au_id='A005'";
Statement stmt = con.createStatement();
int count = stmt.executeUpdate(str);
```

In the preceding code snippet, `str` contains the `DELETE` statement that you need to send to a database. The `Statement` object executes this statement using the `executeUpdate()` method and returns the number of rows deleted from the table to the `count` variable.

Creating a Table

You can use the `CREATE TABLE` statement to create and define the structure of a table in a database. You can use the following code snippet in a Java application to create a table:

```
String str="CREATE TABLE Publishers"
+"(pub_id VARCHAR(5),"
+"pub_name VARCHAR(50),"
+"phone INTEGER,"
+"address VARCHAR(50), "
+"city VARCHAR(50), "
+"ZIP VARCHAR(20))";
Statement stmt=con.createStatement();
stmt.execute(str);
```

In the preceding code snippet, `str` contains the `CREATE TABLE` statement to create the `Publishers` table. The `execute()` method is used to process the `CREATE TABLE` statement.

Altering and Dropping a Table

You can use the `ALTER` statement to modify the definition of the database object. You use the `ALTER TABLE` statement to modify the structure of a table. For example, you can use this statement to add a new column in a table, change the data type and width of an existing column, and add a constraint to a column. You can use the following code snippet to use the `ALTER` statement in a Java application to add a column in the `Books` table:

```
String str="ALTER TABLE Books ADD price INTEGER";
Statement stmt=con.createStatement();
stmt.execute(str);
```

You can use the `DROP` statement to drop an object from a database. You use the `DROP TABLE` statement to drop a table from a database. You can use the following code snippet to drop the `MyProduct` table using a Java application:

```
String str="DROP TABLE MyProduct";
Statement stmt=con.createStatement();
stmt.execute(str);
```

While creating JDBC applications, you need to handle exceptions. The `execute()` method can throw `SQLException` while executing SQL statements.

Handling SQL Exceptions

The `java.sql` package provides the `SQLException` class, which is derived from the `java.lang.Exception` class. `SQLException` is thrown by various methods in the JDBC API and enables you to determine the reason for the errors that occur while connecting a Java application to a database. You can catch `SQLException` in a Java application using the `try` and `catch` exception handling block. The `SQLException` class provides the following error information:

- **Error message**: Is a string that describes error.
- **Error code**: Is an integer value that is associated with an error. The error code is vendor specific and depends upon the database in use.
- **SQL state**: Is an *XOPEN* error code that identifies the error. Various vendors provide different error messages to define the same error. As a result, an error may have different error messages. The XOPEN error code is a standard message associated with an error that can identify the error across multiple databases.

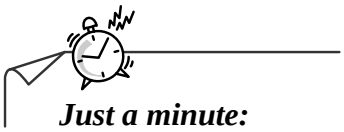
The `SQLException` class contains various methods that provide error information. Some of the methods in the `SQLException` class are:

- `int getErrorCode()`: Returns the error code associated with the error occurred.
- `String getSQLState()`: Returns SQL state for the `SQLException` object.
- `SQLException getNextException()`: Returns the next exception in the chain of exceptions.

You can use the following code snippet to catch `SQLException`:

```
try
{
      String str = "DELETE FROM Authors WHERE au_id='A002'";
      Statement stmt = con.createStatement();
      int count = stmt.executeUpdate(str);
}
catch(SQLException sqlExceptionObject)
{
      System.out.println("Display Error Code");
           System.out.println("SQL Exception "+
           sqlExceptionObject.getErrorCode());
}
```

In the preceding code snippet, if the `DELETE` statement throws `SQLException`, then it is handled by the catch block. `sqlExceptionObject` is an object of the `SQLException` class and is used to invoke the `getErrorCode()` method.



Just a minute:

Identify the interface of the `java.sql` *package that must be implemented by all the JDBC driver classes.*

Answer:

`Driver`

Activity 9.1: Creating a JDBC Application to Query a Database

Accessing Result Sets

When you execute a query to retrieve data from a table using a Java application, the output of the query is stored in a `ResultSet` object in a tabular format. A `ResultSet` object maintains a *cursor* that enables you to move through the rows stored in the `ResultSet` object. By default, the `ResultSet` object maintains a cursor that moves in the forward direction only. As a result, it moves from the first row to the last row in `ResultSet`. In addition, the default `ResultSet` object is not updatable, which means that the rows cannot be updated in the default object. The cursor in the `ResultSet` object initially points before the first row.

Types of Result Sets

You can create various types of `ResultSet` objects to store the output returned by a database after executing SQL statements. The various types of `ResultSet` objects are:

- **Read only**: Allows you to only read the rows in a `ResultSet` object.
- **Forward only**: Allows you to move the result set cursor from the first row to the last row in the forward direction only.
- **Scrollable**: Allows you to move the result set cursor forward or backward through the result set.
- **Updatable**: Allows you to update the result set rows retrieved from a database table.

You can specify the type of a `ResultSet` object using the `createStatement()` method of the `Connection` interface. The `createStatement()` method accepts the `ResultSet` fields as parameters to create different types of the `ResultSet` object. The following table lists various fields of the `ResultSet` interface.

ResultSet Field	***Description***
TYPE_SCROLL_SENSITIVE	*Specifies that the cursor of the `ResultSet` object is scrollable and reflects the changes in the data made by other users.*
TYPE_SCROLL_INSENSITIVE	*Specifies that the cursor of the `ResultSet` object is scrollable and does not reflect changes in the data made by other users.*
TYPE_FORWARD_ONLY	*Specifies that the cursor of the `ResultSet` object moves in forward direction only from the first row to the last row.*
CONCUR_READ_ONLY	*Specifies the concurrency mode that does not allow you to update the `ResultSet` object.*

ResultSet Field	*Description*
`CONCUR_UPDATABLE`	*Specifies the concurrency mode that allows you to update the* `ResultSet` *object.*
`CLOSE_CURSOR_AT_COMMIT`	*Specifies the holdability mode that closes the open* `ResultSet` *object when the current transaction is committed.*
`HOLD_CURSOR_OVER_COMMIT`	*Specifies the holdability mode that keeps the* `ResultSet` *object open when the current transaction is committed.*

The Fields of the ResultSet Interface

The `createStatement()` method has the following overloaded forms:

- `Statement createStatement()`: Does not accept any parameter. This method creates a `Statement` object for sending SQL statements to the database. It creates the default `ResultSet` object that only allows forward scrolling.
- `Statement createStatement(int resultSetType, int resultSetConcurrency)`: Accepts two parameters. The first parameter indicates the `ResultSet` type that determines whether or not a result set cursor is scrollable or forward only. The second parameter indicates the concurrency mode for the result set that determines whether the data in result set is updateable or read only. This method creates a `ResultSet` object with the given type and concurrency.
- `Statement createStatement(int resultSetType, int resultSetConcurrency, int resultSetHoldability)`: Accepts three parameters. Apart from the `ResultSet` types and the concurrency mode, this method also accepts a third parameter. This parameter indicates the holdability mode for the open result set object. This method creates a `ResultSet` object with the given type, concurrency, and the holdability mode.

Methods of the ResultSet Interface

The `ResultSet` interface contains various methods that enable you to move the cursor through the result set. The following table lists some methods of the `ResultSet` interface that are commonly used.

Method	***Description***
`boolean first()`	*Shifts the control of a result set cursor to the first row of the result set.*
`boolean isFirst()`	*Determines whether the result set cursor points to the first row of the result set.*
`void beforeFirst()`	*Shifts the control of a result set cursor before the first row of the result set.*
`boolean isBeforeFirst()`	*Determines whether the result set cursor points before the first row of the result set.*
`boolean last()`	*Shifts the control of a result set cursor to the last row of the result set.*
`boolean isLast()`	*Determines whether the result set cursor points to the last row of the result set.*
`void afterLast()`	*Shifts the control of a result set cursor after the last row of the result set.*
`boolean isAfterLast()`	*Determines whether the result set cursor points after the last row of the result set.*
`boolean previous()`	*Shifts the control of a result set cursor to the previous row of the result set.*
`boolean absolute(int i)`	*Shifts the control of a result set cursor to the row number that you specify as a parameter.*
`boolean relative(int i)`	*Shifts the control of a result set cursor, forward or backward, relative to the row number that you specify as a parameter. This method accepts either a positive value or a negative value as a parameter.*

The Methods of the ResultSet Interface

You can create a scrollable result set that scrolls backward or forward through the rows in the result set. You can use the following code snippet to create a read-only scrollable result set:

```
Statement stmt = con.createStatement(ResultSet.TYPE_SCROLL_INSENSITIVE,
ResultSet.CONCUR_READ_ONLY);
ResultSet rs=stmt.executeQuery ("SELECT * FROM Authors");
```

You can determine the location of the result set cursor using the methods in the `ResultSet` interface. You can use the following code snippet to determine if the result set cursor is before the first row in the result set:

```
if(rs.isBeforeFirst()==true)
System.out.println("Result set cursor is before the first row in the result
set");
```

In the preceding code snippet, `rs` is the `ResultSet` object that calls the `isBeforeFirst()` method.

You can move to a particular row, such as first or last, in the result set using the methods in the `ResultSet` interface. You can use the following code snippet to move the result set cursor to the first row in the result set:

```
if(rs.first()==true)
System.out.println(rs.getString(1) + ", " + rs.getString(2)+ ", " +
rs.getString(3));
```

In the preceding code snippet, `rs` is the `ResultSet` object that calls the `first()` method.

Similarly, you can move the result set cursor to the last row in the result set using the `last()` method.

To move to any particular row of a result set, you can use the `absolute()` method. For example, if the result set cursor is at the first row and you want to scroll to the fourth row, you should enter 4 as a parameter when you call the `absolute()` method, as shown in the following code snippet:

```
System.out.println("Using absolute() method");
rs.absolute(4);
int rowcount = rs.getRow();
System.out.println("row number is " + rowcount);
```

Note

You can pass a negative value to the `absolute()` method to set the cursor to a row with regard to the last row of the result set. For example, to set the cursor to the row preceding the last row, specify `rs.absolute(-2)`.

JDBC allows you to create an updateable result set that enables you to modify the rows in the result set. The following table lists some of the methods used with the updatable result set.

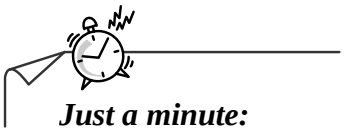
Method	***Description***
`void updateRow()`	*Updates the current row of the `ResultSet` object and updates the same in the underlying database table.*
`void insertRow()`	*Inserts a row in the current `ResultSet` object and the underlying database table.*
`void deleteRow()`	*Deletes the current row from the `ResultSet` object and the underlying database table.*
`void updateString(int columnIndex, String x)`	*Updates the specified column with the given string value. It accepts the column index whose value needs to be changed.*
`void updateString(String columnLabel, String x)`	*Updates the specified column with the given string value. It accepts the column name whose value needs to be changed.*
`void updateInt(int columnIndex, int x)`	*Updates the specified column with the given `int` value. It accepts the column index whose value needs to be changed.*
`void updateInt(String columnLabel, int x)`	*Updates the specified column with the given `int` value. It accepts the column name whose value needs to be changed.*

The Methods Used With the Updatable ResultSet

You can use the following code snippet to modify the information of the author using the updatable result set:

```
Statement stmt = con.createStatement();
stmt = con.createStatement(ResultSet.TYPE_SCROLL_SENSITIVE,
ResultSet.CONCUR_UPDATABLE);
ResultSet rs = stmt.executeQuery("SELECT au_id, city, state FROM Authors
WHERE au_id='A004'");
rs.next();
rs.updateString("state", "NY");
rs.updateString("city", "Columbia");
rs.updateRow();
```

In the preceding code snippet, the row is retrieved from the `Authors` table where the author id is `A004`. In the retrieved row, the value in the `state` column is changed to `NY` and the value in the `city` column is changed to `Columbia`.



Just a minute:

Identify the field of the `ResultSet` *interface that allows the cursor to be scrollable and reflects the changes in the data.*

1. `TYPE_SCROLL_SENSITIVE`
2. `TYPE_SCROLL_INSENSITIVE`
3. `CONCUR_READ_ONLY`
4. `CONCUR_UPDATAB`

Answer:

1. `TYPE_SCROLL_SENSITIVE`

In addition to `ResultSet`, Java provides `RowSet`. The `RowSet` interface provides the connected and disconnected environments. In a connected environment the `RowSet` object uses a JDBC driver to make a connection to the underlying database and maintains the connection throughout its life time. On the other hand, in a disconnected environment, the `RowSet` object makes a connection to the underlying database only to read data from the `ResultSet` object or write back to the database. After reading or writing data, the `RowSet` object disconnects the connection.

To establish the connected or disconnected environment, the JDBC API provides the following interfaces:

- `JdbcRowSet`: Provides the connected environment that is most similar to the `ResultSet` object. It makes the `ResultSet` object scrollable and updateable.
- `CachedRowSet`: Provides the disconnected environment. It has all the capabilities of the `JdbcRowSet` object. In addition, it has the following additional features:
  - It obtains a connection to a data source and executes the query.
  - It reads the data from the `ResultSet` object and fills the data in the `CachedRowSet` object.
  - It changes the data while it is disconnected.
  - It reconnects to the data source to write the changes back to it.
  - It checks and resolves the conflicts with the data source.
- `WebRowSet`: Provides the disconnected environment. It has all the capabilities of the `CachedRowSet` object. In addition, it can convert its objects into an Extensible Markup Language (XML) document. Further, it can also use the XML document to populate its object.
- `JoinRowSet`: Provides the disconnected environment. It has all the capabilities of the `WebRowSet` object. In addition, it allows you to create `SQL JOIN` between the `RowSet` objects.
- `FilteredRowSet`: Provides the disconnected environment. It has all the capabilities of the `JoinRowSet` object. In addition, it applies filter to make the selected data available.

The preceding interfaces can be used for specific need, such as connected or disconnected. However, there is another way to provide the `RowSet` implementation. For this, the `RowSetProvider` class provides APIs to get a `RowSetFactory` implementation that can be used to instantiate a proper `RowSet` implementation. It provides the following two methods:

- `static RowSetFactory newFactory()`: Is used to create an instance of the `RowSetFactory` implementation.
- `static RowSetFactory newFactory(String factoryClassName, ClassLoader c1)`: Is used to create an instance of the `RowSetFactory` from the specified factory class name.

The `RowSetFactory` interface defines the implementation of a factory that is used to obtain different types of `RowSet` implementations. It provides the following five methods:

- `CachedRowSet createCachedRowSet()`: Is used to create an instance of `CachedRowSet`.
- `FilteredRowSet createFilteredRowSet()`: Is used to create an instance of `FilteredRowSet`.
- `JdbcRowSet createJdbcRowSet()`: Is used to create an instance of `JdbcRowSet`.
- `JoinRowSet createJoinRowSet()`: Is used to create an instance of `JoinRowSet`.
- `WebRowSet createWebRowSet()`: Is used to create an instance of `WebRowSet`.

Practice Questions

1. Which one of the following methods is used to move the cursor to a particular row in a result set?
   a. `absolute()`
   b. `first()`
   c. `isFirst()`
   d. `relative()`

2. Which one of the following components of the JDBC URL indicates the vendor of RDBMS?
   a. Subname
   b. Supername
   c. Subprotocol name
   d. Superprotocol name

3. Identify the field of the `ResultSet` interface that specifies the cursor to be scrollable and does not reflect the changes in the data.
   a. `TYPE_SCROLL_INSENSITIVE`
   b. `TYPE_FORWARD_ONLY`
   c. `TYPE_SCROLL_SENSITIVE`
   d. `TYPE_READ_ONLY`

4. The `Connection` object provides the _____ method to create a `Statement` object.

5. Which one of the following Java drivers interacts with the database directly using a vendor-specific network protocol?
   a. JDBC-ODBC Bridge driver
   b. Native-API driver
   c. Network Protocol driver
   d. Native Protocol driver

Summary

In this chapter, you learned that:

- The JDBC architecture has the following two layers:
  - JDBC application layer
  - JDBC driver layer
- JDBC supports the following four types of drivers:
  - JDBC-ODBC Bridge driver
  - Native-API driver
  - Network Protocol driver
  - Native Protocol driver
- The classes and interfaces of the JDBC API are defined in the `java.sql` and `javax.sql` packages.
- You can load a driver and register it with the driver manager by using the `forName()` method or the `registerDriver()` method.
- A `Connection` object establishes a connection between a Java application and a database.
- A `Statement` object sends a request and retrieves results to/ from a database.
- You can insert, update, and delete data from a table using the DML statements in Java applications.
- You can create, alter, and drop tables from a database using the DDL statements in Java applications.
- Once the SQL statements are executed, a `ResultSet` object stores the result retrieved from a database.
- You can create various types of the `ResultSet` objects, such as read only, updatable, and forward only.

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Creating Applications Using Advanced Features of JDBC

CHAPTER 10

You have learned how to insert, delete, and update database tables using the `java.sql.Statement` object. However, by using this object, you can use only static values for insertion, updation, or deletion. Therefore, to work with dynamic values, Java provides the `java.sql.PreparedStatement` object.

At times, while executing the transactions in database, all statements within the transaction should either execute successfully or fail. To implement this functionality, Java provides database transaction management. In addition, to improve the efficiency of the application, Java provides batch updates. Further, to work with SQL procedures and functions, Java provides `java.sql.CallableStatement`. Thereafter, to work with metadata of database and tables, Java provides `java.sql.DatabaseMetaData` and `java.sql.ResultSetMetaData`.

This chapter focuses on creating application using `java.sql.PreparedStatement`, managing database transaction, performing batch updates, creating applications using `java.sql.CallableStatement`, and creating application to use the metadata of database and tables.

Objectives

In this chapter, you will learn to:

- Create applications using the PreparedStatement object
- Manage database transactions
- Implement batch updates in JDBC
- Create and call stored procedures in JDBC
- Use metadata in JDBC

Creating Applications Using the PreparedStatement Object

Consider a scenario where New Publishers, a publishing house, maintains details about books and authors in a database. The management of New Publishers wants an application that can help them access the details about authors based on different criteria. For example, the application should be able to retrieve the details of all the authors living in a particular city specified at runtime. In this scenario, you cannot use the `Statement` object to retrieve the details because the value for the city needs to be specified at runtime. You need to use the `PreparedStatement` object as it can accept runtime parameters.

The `PreparedStatement` interface is derived from the `Statement` interface and is available in the `java.sql` package. The `PreparedStatement` object allows you to pass runtime parameters to the SQL statements to query and modify the data in a table.

The `PreparedStatement` objects are compiled and prepared only once by JDBC. The further invocation of the `PreparedStatement` object does not recompile the SQL statements. This helps in reducing the load on the database server and improves the performance of the application.

Methods of the PreparedStatement Interface

The `PreparedStatement` interface inherits the following methods to execute the SQL statements from the `Statement` interface:

- `ResultSet executeQuery()`: Is used to execute the SQL statement and returns the result in a `ResultSet` object.
- `int executeUpdate()`: Executes an SQL statement, such as `INSERT`, `UPDATE`, or `DELETE`, and returns the count of the rows affected.
- `boolean execute()`: Executes an SQL statement and returns the `boolean` value.

Consider an example where you have to retrieve the details of an author by passing the author id at runtime. For this, the following SQL statement with a parameterized query can be used:

```
SELECT * FROM Authors WHERE au_id = ?
```

To submit such a parameterized query to a database from an application, you need to create a `PreparedStatement` object using the `prepareStatement()` method of the `Connection` object. You can use the following code snippet to prepare an SQL statement that accepts values at runtime:

```
stat=con.prepareStatement("SELECT * FROM Authors WHERE au_id = ?");
```

The `prepareStatement()` method of the `Connection` object takes an SQL statement as a parameter. The SQL statement can contain the symbol, `?`, as a placeholder that can be replaced by input parameters at runtime.

Before the SQL statement specified in the `PreparedStatement` object is executed, you must set the value of each `?` parameter. The value can be set by calling an appropriate `setXXX()` method, where `XXX` is the data type of the parameter.

For example, consider the following code snippet:

```
stat.setString(1,"A001");
ResultSet result=stat.executeQuery();
```

In the preceding code snippet, the first parameter of the `setString()` method specifies the index value of the `?` placeholder, and the second parameter is used to set the value of the `?` placeholder. You can use the following code snippet when the value for the `?` placeholder is obtained from the user interface:

```
stat.setString(1,aid.getText());
ResultSet result=stat.executeQuery();
```

In the preceding code snippet, the `setString()` method is used to set the value of the `?` placeholder with the value retrieved at runtime from the `aid` textbox of the user interface.

The `PreparedStatement` interface provides various methods to set the value of placeholders for the specific data types. The following table lists some commonly used methods of the `PreparedStatement` interface.

Method	***Description***
`void setByte(int index, byte val)`	*Sets the Java `byte` type value for the parameter corresponding to the specified index.*
`void setBytes(int index, byte[] val)`	*Sets the Java `byte` type array for the parameter corresponding to the specified index.*
`void setBoolean(int index, boolean val)`	*Sets the Java `boolean` type value for the parameter corresponding to the specified index.*
`void setDouble(int index, double val)`	*Sets the Java `double` type value for the parameter corresponding to the specified index.*
`void setInt(int index, int val)`	*Sets the Java `int` type value for the parameter corresponding to the specified index.*
`void setLong(int index, long val)`	*Sets the Java `long` type value for the parameter corresponding to the specified index.*
`void setFloat(int index, float val)`	*Sets the Java `float` type value for the parameter corresponding to the specified index.*
`void setShort(int index, short val)`	*Sets the Java `short` type value for the parameter corresponding to the specified index.*
`void setString(int index, String val)`	*Sets the Java `String` type value for the parameter corresponding to the specified index.*

The Methods of the PreparedStatement Interface

Retrieving Rows

You can use the following code snippet to retrieve the details of the books written by an author from the `Books` table by using the `PreparedStatement` object:

```
String str = "SELECT * FROM Books WHERE au_id = ?";
PreparedStatement ps= con.prepareStatement(str);
ps.setString(1, "A001");
ResultSet rs=ps.executeQuery();
while(rs.next())
{
     System.out.println(rs.getString(1) + " " + rs.getString(2));
}
```

In the preceding code snippet, the `str` variable stores the `SELECT` statement that contains one input parameter. The `setString()` method is used to set the value for the `au_id` attribute of the `Books` table. The `SELECT` statement is executed using the `executeQuery()` method, which returns a `ResultSet` object.

Inserting Rows

You can use the following code snippet to create a `PreparedStatement` object that inserts a row into the `Authors` table by passing the author's data at runtime:

```
String str = "INSERT INTO Authors (au_id, au_name) VALUES (?,?)";
PreparedStatement ps = con.prepareStatement(str);
ps.setString(1, "1001");
ps.setString(2, "Abraham White");
int rt=ps.executeUpdate();
```

In the preceding code snippet, the `str` variable stores the `INSERT` statement that contains two input parameters. The `setString()` method is used to set the values for the `au_id` and `au_name` columns of the `Authors` table. The `INSERT` statement is executed using the `executeUpdate()` method, which returns an integer value that specifies the number of rows inserted into the table.

Updating and Deleting Rows

You can use the following code snippet to modify the state to `CA` where city is `Oakland` in the `Authors` table by using the `PreparedStatement` object:

```
String str = "UPDATE Authors SET state= ? WHERE city= ? ";
PreparedStatement ps = con.prepareStatement(str);
ps.setString(1, "CA");
ps.setString(2, "Oakland");
int rt=ps.executeUpdate();
```

In the preceding code snippet, two input parameters, `state` and `city`, contain the values for the `state` and `city` attributes of the `Authors` table, respectively.

You can use the following code snippet to delete a row from the `Authors` table, where `au_name` is `Abraham White` by using the `PreparedStatement` object:

```
String str = "DELETE FROM Authors WHERE au_name= ? ";
PreparedStatement ps = con.prepareStatement(str);
ps.setString(1, "Abraham White");
int rt=ps.executeUpdate();
```

Just a minute:

Identity the three methods of the `PreparedStatement` interface.

Answer:

The three methods of the `PreparedStatement` interface are:

1. `ResultSet executeQuery()`
2. `int executeUpdate()`
3. `boolean execute()`

Activity 10.1: Creating an Application that Uses the PreparedStatement Object

Managing Database Transactions

A transaction is a set of one or more SQL statements executed as a single unit. A transaction is complete only when all the SQL statements in a transaction execute successfully. If any one of the SQL statements in the transaction fails, the entire transaction is rolled back, thereby, maintaining the consistency of the data in the database.

JDBC API provides the support for transaction management. For example, a JDBC application is used to transfer money from one bank account to another. This transaction gets completed when the money is deducted from the first account and added to the second. If an error occurs while processing the SQL statements, both the accounts remain unchanged. The set of the SQL statements, which transfers money from one account to another, represents a transaction in the JDBC application.

The database transactions can be committed in the following two ways in the JDBC applications:

- **Implicit**: The `Connection` object uses the *auto-commit* mode to execute the SQL statements implicitly. The auto-commit mode specifies that each SQL statement in a transaction is committed automatically as soon as the execution of the SQL statement completes. By default, all the transaction statements in a JDBC application are auto-committed.
- **Explicit**: For explicitly committing a transaction statement in a JDBC application, you need to use the `setAutoCommit()` method. This method accepts either of the two values, `true` or `false`, to set or reset the auto-commit mode for a database. The auto-commit mode is set to `false` to commit a transaction explicitly. You can set the auto-commit mode to `false` using the following code snippet:

  ```
  con.setAutoCommit(false);
  ```

  In the preceding code snippet, `con` represents a `Connection` object.

Committing a Transaction

When you set the auto-commit mode to `false`, the operations performed by the SQL statements are not reflected permanently in a database. You need to explicitly call the `commit()` method of the `Connection` interface to reflect the changes made by the transactions in a database. All the SQL statements that appear between the `setAutoCommit(false)` method and the `commit()` method are treated as a single transaction and executed as a single unit.

The `rollback()` method is used to undo the changes made in the database after the last commit operation. You need to explicitly invoke the `rollback()` method to revert a database in the last committed state. When the `rollback()` method is invoked, all the pending transactions of a database are cancelled and the database gets reverted to the state in which it was committed previously. You can call the `rollback()` method using the following code snippet:

```
con.rollback();
```

In the preceding code snippet, `con` represents a `Connection` object.

You can use the following code to create a transaction that includes two `INSERT` statements and the transaction is committed explicitly using the `commit()` method:

```
import java.sql.*;
public class CreateTrans
{
    public static void main(String arg[])
    {
        try
        {
            /*Initialize and load the Type 4 JDBC driver*/
            Class.forName("com.microsoft.sqlserver.jdbc.SQLServerDriver");

            /*Establish a connection with a data source*/
            try (Connection con =
DriverManager.getConnection("jdbc:sqlserver://sqlserver01;databaseName=Librar
y;user=user1;password=password#1234");)
            {
                /*Set the auto commit mode to false*/
                con.setAutoCommit(false);

                /*Create a transaction*/
                try (PreparedStatement ps = con.prepareStatement("INSERT INTO
Publishers (pub_id, pub_name) VALUES (?, ?)");)
                {
                    /*Specify the value for the placeholders in the
PreparedStatement object*/
                    ps.setString(1, "P006");
                    ps.setString(2, "Darwin Press");
                    int firstctr = ps.executeUpdate();
                    System.out.println("First Row Inserted but not
committed");

                    /*Insert a row in the database table using the
prepareStatement() method*/
                    try (PreparedStatement ps2 = con.prepareStatement("INSERT
INTO Publishers(pub_id, pub_name) VALUES (?, ?)");)
                    {
                        ps2.setString(1, "P007");
                        ps2.setString(2, "MainStream Publishing");
                        int secondctr = ps2.executeUpdate();
                        System.out.println("Second Row Inserted but not
committed");

                        /*Commit a transaction*/
                        con.commit();
                        System.out.println("Transaction Committed, Please
check table for data");

                    }
                }
            }
        }
```

```
            catch (Exception e)
            {
                System.out.println("Error : " + e);
            }
        }
    }
```

In the preceding code, the auto-commit mode is set to `false` using the `setAutoCommit()` method. All the statements that are executed after setting the auto-commit mode to `false` are treated as a transaction by the database.

Just a minute:

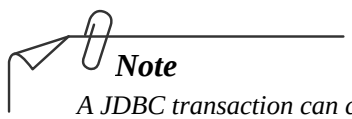
How can you commit a transaction explicitly?

Answer:

You can commit a transaction explicitly by setting the auto-commit mode to `false` and using the `commit()` method.

Implementing Batch Updates in JDBC

A *batch* is a group of update statements sent to a database to be executed as a single unit. You send the batch to a database in a single request using the same `Connection` object. This reduces network calls between the application and the database. Therefore, processing multiple SQL statements in a batch is a more efficient way as compared to processing a single SQL statement.



Note

A JDBC transaction can consist of multiple batches.

The `Statement` interface provides following methods to create and execute a batch of SQL statements:

- `void addBatch(String sql)`: Adds an SQL statement to a batch.
- `int[] executeBatch()`: Sends a batch to a database for processing and returns the total number of rows updated.
- `void clearBatch()`: Removes the SQL statements from the batch.

You can create a `Statement` object to perform batch updates. When the `Statement` object is created, an empty array gets associated with the object. You can add multiple SQL statements to the empty array for executing them as a batch. You also need to disable the auto-commit mode using the `setAutoCommit(false)` method while working with batch updates in JDBC. This enables you to roll back the entire transaction performed using a batch of updates if any SQL statement in the batch fails. You can use the following code snippet to create a batch of SQL statements:

```
con.setAutoCommit(false);
Statement stmt=con.createStatement();
stmt.addBatch("INSERT INTO Publishers (pub_id, pub_name) VALUES (P001, 'Sage
Publications')");
stmt.addBatch("INSERT INTO Product (pub_id, pub_name) VALUES (P002, 'Prisidio
Press')");
```

In the preceding code snippet, `con` is a `Connection` object. The `setAutoCommit()` method is used to set the auto-commit mode to `false`. The batch contains two `INSERT` statements that are added to the batch using the `addBatch()` method.

The SQL statements in a batch are processed in the order in which the statements appear in a batch. You can use the following code snippet to execute a batch of SQL statements:

```
int[] updcount=stmt.executeBatch();
```

In the preceding code snippet, `updcount` is an integer array that stores the values of the update count returned by the `executeBatch()` method. The update count is the total number of rows affected when an SQL statement is processed. The `executeBatch()` method returns the updated count for each SQL statement in a batch, if it is successfully processed.

Exception Handling in Batch Updates

The batch update operations can throw two types of exceptions, `SQLException` and `BatchUpdateException`. The JDBC API methods, `addBatch()` and `executeBatch()`, throw `SQLException` when any problem occurs while accessing a database. The `SQLException` exception is thrown when you try to execute a `SELECT` statement using the `executeBatch()` method. The `BatchUpdateException` class is derived from the `SQLException` class. The `BatchUpdateException` exception is thrown when the SQL statements in the batch cannot be executed due to:

- Presence of illegal arguments in the SQL statement.
- Absence of the database table.

`BatchUpdateException` uses an array of the update count to identify the SQL statement that throws the exception. The update count for all the SQL statements that are executed successfully is stored in the array in the same order in which the SQL statements appear in the batch. You can traverse the array of the update count to determine the SQL statement that is not executed successfully in a batch. The `null` value in an array of the update count indicates that the SQL statement in the batch failed to execute. You can use the following code to use the methods of the `SQLException` class that can be used to print the update counts for the SQL statements in a batch by using the `BatchUpdateException` object:

```
import java.sql.*;

public class BatchUpdate
{
    public static void main(String args[])
    {
        try
        {
            /*Batch Update Code comes here*/
        }
        catch (BatchUpdateException bexp)
        {
            /*Use the getMessage() method to retrieve the message associated
with the exception thrown*/
            System.err.println("SQL Exception:" + bexp.getMessage());
            System.err.println("Update Counts:");
            /*Use the getUpdateCount() method to retrieve the update count
for each SQL statement in a batch*/
            int[] updcount = bexp.getUpdateCounts();
            for (int i = 0; i <= updcount.length; i++)
            {
                /*Print the update count*/
                System.err.println(updcount[i]);
            }
        }
    }
}
```

Creating an Application to Insert Rows in a Table Using Batch Updates

You can execute multiple objects of the `Statement` and `PreparedStatement` interfaces together as batches in a JDBC application using batch updates. You can use the following code to insert data in a table using batch updates:

```
import java.sql.*;

public class BookInfo
{
    public static void main(String args[])
    {
        try
        {
            /*Initialize and load Type 4 JDBC driver*/
            Class.forName("com.microsoft.sqlserver.jdbc.SQLServerDriver");

            /*Connect to a data source using Library DSN*/
            try (Connection con =
DriverManager.getConnection("jdbc:sqlserver://sqlserver01;databaseName=Librar
y;user=user1;password=password#1234");
                    /*Create a Statement object*/
                    Statement stmt = con.createStatement();)
            {
                con.setAutoCommit(false);

                /*Add the INSERT statements to a batch*/
                stmt.addBatch("INSERT INTO Books (book_id, book_name) VALUES
('B004', 'Kane and Able')");
                stmt.addBatch("INSERT INTO Books (book_id, book_name) VALUES
('B005', 'The Ghost')");
                stmt.addBatch("INSERT INTO Books (book_id, book_name) VALUES
('B006', 'If Tommorrow Comes')");

                /*Execute a batch using executeBatch() method*/
                int[] results = stmt.executeBatch();
                System.out.println("");
                System.out.println("Using Statement object");
                System.out.println("-------------------------");
                for (int i = 0; i < results.length; i++)
                {
                    System.out.println("Rows affected by " + (i + 1) + "
INSERT statement: " + results[i]);
                }

                /*Use the PreparedStatement object to perform batch updates*/
                try (PreparedStatement ps = con.prepareStatement("INSERT INTO
Books (book_id, price) VALUES ( ?, ?)");)
                {
                    System.out.println("");
                    System.out.println("---------------------------------");
                    System.out.println("Using PreparedStatement object");
                    System.out.println("---------------------------------");
```

```
                        /*Specify the value for the placeholders*/
                        ps.setString(1, "B007");
                        ps.setInt(2, 575);
                        ps.addBatch();
                        ps.setString(1, "B008");
                        ps.setInt(2, 350);

                        /*Add the SQL statement to the batch*/
                        ps.addBatch();

                        /*Execute the batch of SQL statements*/
                        int[] numUpdates = ps.executeBatch();
                        for (int i = 0; i < numUpdates.length; i++)
                        {
                            System.err.println("Rows affected by " + (i + 1) + "
    INSERT statement: " + numUpdates[i]);
                        }

                        /*Commit the INSERT statements in the batch*/
                        con.commit();


                    }
                }
            }
            catch (BatchUpdateException bue)
            {
                System.out.println("Error : " + bue);
            }
            catch (SQLException sqle)
            {
                System.out.println("Error : " + sqle);
            }
            catch (Exception e) {
                System.out.println("Error : " + e);
            }
        }
    }
```

In the preceding code, two batches are created using the `Statement` and `PreparedStatement` objects. The `INSERT` statements are added to the batch using the `addBatch()` method and are executed using the `executeBatch()` method. The `executeBatch()` method returns an array, which stores the update count for all the SQL statements in the batch. You can display the number of rows affected by each SQL statement in the batch using the `for` loop.

Creating and Calling Stored Procedures in JDBC

The java.sql package provides the CallableStatement interface that contains various methods to enable you to call database stored procedures. The CallableStatement interface is derived from the PreparedStatement interface.

Creating Stored Procedures

Stored procedures can be created using JDBC applications. You can use the executeUpdate() method to execute the CREATE PROCEDURE SQL statement. Stored procedures can be of two types, parameterized and non parameterized.

You can use the following code snippet to create a non parameterized stored procedure in a JDBC application:

```
String str = "CREATE PROCEDURE Authors_info "
+"AS "
+ "SELECT au_id,au_name "
+ "FROM Authors "
+ "WHERE city = 'Oakland' "
+ "ORDER BY au_name";
Statement stmt=con.createStatement();
int rt=stmt.executeUpdate(str);
```

In the preceding code snippet, the SELECT statement specifies that the data is retrieved from the Authors table in the order of the au_name column. The Connection object con is used to send the CREATE PROCEDURE SQL statement to a database. When you execute the code, the Authors_info stored procedure is created and stored in the database.

You can use the following code snippet to create a parameterized stored procedure:

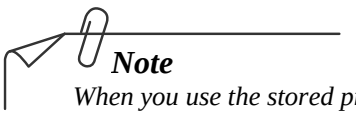
```
str = " CREATE PROCEDURE Authors_info_prmtz @auth_id varchar(15) ,@auth_name
varchar(20) output, @auth_city varchar(20) output,@auth_state varchar(20)
output "
+ " AS "
+ " SELECT @auth_name=au_name, @auth_city=city, @auth_state=state "
+ " FROM Authors "
+ " WHERE au_id=@auth_id ";
Statement stmt=con.createStatement();
int rt=stmt.executeUpdate(str);
```

In the preceding code snippet, the Authors_info_prmtz stored procedure is created that accepts the author id as a parameter and retrieves the corresponding author information from the database. The retrieved information is stored in the OUT parameters. The output keyword is used to represent OUT parameters.

A stored procedure can accept one or multiple parameters. A parameter of a stored procedure can take any of the following forms:

- IN: Refers to the argument that you pass to a stored procedure.
- OUT: Refers to the return value of a stored procedure.

- `INOUT`: Combines the functionality of the `IN` and `OUT` parameters. The `INOUT` parameter enables you to pass an argument to a stored procedure. The same parameter can also be used to store a return value of a stored procedure.



Note

When you use the stored procedures to perform database operations, it reduces network traffic because instead of sending multiple SQL statements to a database, a single stored procedure is executed.

Calling a Stored Procedure Without Parameters

The `Connection` interface provides the `prepareCall()` method that is used to create the `CallableStatement` object. This object is used to call a stored procedure of a database. The `prepareCall()` method is an overloaded method that has various forms. Some of the commonly used forms are:

- `CallableStatement prepareCall(String str)`: Creates a `CallableStatement` object to call a stored procedure. The `prepareCall()` method accepts a string as a parameter that contains an SQL statement to call a stored procedure. You can also specify the placeholders to accept parameters in the SQL statement.
- `CallableStatement prepareCall(String str, int resSetType, int resSetConcurrency)`: Creates a `CallableStatement` object that returns the `ResultSet` object, which has the specified result set type and concurrency mode. The method accepts the following three parameters:
  - `String` object: Contains an SQL statement to call a stored procedure. The SQL statement can contain one or more parameters.
  - `ResultSet` types: Specifies any of the three `Resultset` types, `TYPE_FORWARD_ONLY`, `TYPE_SCROLL_INSENSITIVE`, or `TYPE_SCROLL_SENSITIVE`.
  - `ResultSet` concurrency modes: Specifies either of these concurrency modes, `CONCUR_READ_ONLY` or `CONCUR_UPDATABLE`, for a result set.
- `CallableStatement prepareCall(String str, int resSetType, int resSetConcurrency, int resSetHoldability)`: Creates a `CallableStatement` object that returns a `ResultSet` object that has the specified result type, concurrency mode, and constant to set the result set state.

The following signature is used to call a stored procedure without parameters:

```
exec <procedure_name>
```

You can use the following code snippet to call a stored procedure that does not accept parameters:

```
String str = "exec Authors_info";
            CallableStatement cstmt = con.prepareCall(str);
            ResultSet rs = cstmt.executeQuery();
            while (rs.next())
              {
               System.out.println(" Author Id : " + rs.getString(1) + "\t");
              System.out.println(" Author Name : " + rs.getString(2) + "\t");
            }
```

In the preceding code snippet, `con` is the `Connection` object that invokes the `prepareCall()` method. The `str` variable contains the call to the `Authors_info` stored procedure, and this call is passed as a parameter to the `prepareCall()` method.

Calling a Stored Procedure with Parameters

The SQL escape syntax is used to call a stored procedure with parameters. The SQL escape syntax is a standard way to call a stored procedure from RDBMS and is independent of RDBMS. The driver searches the SQL escape syntax in the code and converts the SQL escape syntax into the database compatible form. There are two forms of the SQL escape syntax, one that contains result parameter and the other that does not contain result parameters. Both the forms can take multiple parameters. If the SQL escape syntax contains a result parameter, the result parameter is used to return a value from a stored procedure. The result parameter is an `OUT` parameter. Other parameters of the SQL escape syntax can contain the `IN`, `OUT`, or `INOUT` parameter. The signature of the SQL escape syntax is:

```
{[? =] call <procedure_name> [<parameter1>,<parameter2>, ., <parameterN>]}
```

The placeholders are used to represent the `IN`, `OUT`, and `INOUT` parameters of a stored procedure in the procedure call. The signature to call a stored procedure with parameters is:

```
{ call <procedure_name>(?) };
```

You need to set the value of the `IN` parameters before the `CallableStatement` object is executed. Otherwise, `SQLException` is thrown while processing the stored procedure. The set methods are used to specify the values for the `IN` parameters. The `CallableStatement` interface inherits the set methods from the `PreparedStatement` interface. The signature to set the value of the `IN` parameter is:

```
<CallableStatement_object>.setInt(<value>);
```

In the preceding signature, the `setInt()` method is used to set the value for an integer type, `IN` parameter.

If the stored procedure contains the `OUT` and `INOUT` parameters, these parameters should be registered with the corresponding JDBC types before a call to a stored procedure is processed. The JDBC types determine the Java data types that are used in the get methods while retrieving the values of the `OUT` and `INOUT` parameters. The `registerOut()` method is used to register the parameters. `SQLException` is thrown if the placeholders, representing the `OUT` and `INOUT` parameters, are not registered.

The prototypes of the `registerOut()` method are:

- `registerOut(int index, int stype)`: Accepts the position of the placeholder and a constant in the `java.sql.Types` class as parameters. The `java.sql.Types` class contains constants for various JDBC types. For example, if you want to register the `VARCHAR` SQL data type, you should use the `STRING` constant of the `java.sql.Types` class. You can use the following method call to the `registerOut()` method to register a parameter:

```
cstmt.registerOutParameter(1, java.sql.Types.STRING);
```

- `registerOut(int index, int stype, int scale)`: Accepts the position of a placeholder, a constant in the `java.sql.Types` class, and a scale of the value that is returned as parameters. You need to define the scale of a parameter while registering numeric data types, such as `NUMBER`, `DOUBLE`, and `DECIMAL`. For example, if you want to register the `DECIMAL` SQL data type that has three digits after decimal, the value for the scale parameter should be three. You can use the following code snippet to specify the scale parameter while invoking the `registerOut()` method:

```
cstmt.registerOutParameter(1, java.sql.Types.DECIMAL, 3);
```

You can use the `prepareCall()` method to call a stored procedure that accepts parameters. The `prepareCall()` method returns a result after processing the SQL and control statements defined in the procedure body. You can use the following code to call a stored procedure with parameters:

```
import java.sql.*;

public class CallProc
{

    public static void main(String args[])
    {
        String id, name, address, city;
        try
        {
            String str = "{call Authors_info_prmtz(?, ?, ?, ?)}";

            /*Initialize and load Type 4 JDBC driver*/
            Class.forName("com.microsoft.sqlserver.jdbc.SQLServerDriver");
            /*Establish a connection with the database*/
            try (Connection con =
DriverManager.getConnection("jdbc:sqlserver://sqlserver01;databaseName=Librar
y;user=user1;password=password#1234");
                    /*Call a stored procedure*/
                    CallableStatement cstmt = con.prepareCall(str);)
            {
                /*Pass IN parameter*/
                cstmt.setString(1, "A001");
                /*Register OUT parameters*/
                cstmt.registerOutParameter(2, Types.VARCHAR);
                cstmt.registerOutParameter(3, Types.VARCHAR);
                cstmt.registerOutParameter(4, Types.VARCHAR);
                /*Process the stored procedure*/
                cstmt.execute();
                /*Retrieve Authors information*/
```

```
                    name = cstmt.getString(2);
                    address = cstmt.getString(3);
                    city = cstmt.getString(4);
                    /*Display author information*/
                    System.out.println("");
                    System.out.println("Displaying Author Information");
                    System.out.println("------------------------------");
                    System.out.println("First name: " + name);
                    System.out.println("Address: " + address);
                    System.out.println("City: " + city);

                }
            }
            catch (Exception e)
            {
                System.out.println("Error " + e);
            }
        }
    }
```

In the preceding code, the `Authors_info_prmtz` stored procedure is invoked. This stored procedure accepts one `IN` type parameter and four `OUT` type parameters. The `IN` parameter is used to specify the id of an author whose information you want to retrieve. The `OUT` parameters are used to retrieve the first name, last name, address, and city of the authors. The `setString()` method is used to specify the author id, and the `registerOut()` method is used to register the `OUT` parameters.

Using Metadata in JDBC

Metadata is the information about data, such as structure and properties of table. For example, a database contains the `employee` table that has the `name`, `address`, `salary`, `designation`, and `department` columns. The metadata of the `employee` table includes certain information, such as names of the columns, data type of each column, and constraints to enter data values in the columns. JDBC API provides the following two metadata interfaces to retrieve the information about the database and the result set:

- `DatabaseMetaData`
- `ResultSetMetaData`

Using the DatabaseMetaData Interface

The `DatabaseMetaData` interface provides the methods that enable you to determine the properties of a database. These properties include names of database tables, database version, SQL keywords, and isolation levels of the data stored in the database.

You can create an object of `DatabaseMetaData` using the `getMetaData()` method of the `Connection` interface. You can use the following code snippet to create an object of the `DatabaseMetaData` interface:

```
DatabaseMetaData dm=con.getMetaData();
```

In the preceding code snippet, `con` refers to an object of the `Connection` interface.

The methods declared in the `DatabaseMetaData` interface retrieve the database-specific information. The following table lists some commonly used methods of the `DatabaseMetaData` interface.

Method	***Description***
`ResultSet getColumns(String catalog, String schema, String table_name, String column_name)`	*Retrieves the information about a column of a database table that is available in the specified database catalog.*
`Connection getConnection()`	*Retrieves the database connection that creates the `DatabaseMetaData` object.*
`String getDriverName()`	*Retrieves the name of the JDBC driver for the `DatabaseMetaData` object.*
`String getDriverVersion()`	*Retrieves the version of the JDBC driver.*

Method	*Description*
`ResultSet getPrimaryKeys(String catalog, String schema, String table)`	*Retrieves the information about the primary keys of the database tables.*
`String getURL()`	*Retrieves the URL of the database.*
`boolean isReadOnly()`	*Returns a* `boolean` *value that indicates whether the database is read only.*
`boolean supportsSavepoints()`	*Returns a* `boolean` *value that indicates whether the database supports savepoints.*

The Methods of the DatabaseMetaData Interface

The methods in the `DatabaseMetaData` interface retrieve information about the database to which a Java application is connected. You can use the following code to retrieve and display the names of various database tables by using the methods of the `DatabaseMetaData` interface:

```
import java.sql.*;

public class TableNames
{
    public static void main(String args[])
    {
        try {
            /*Initialize and load the Type 4 driver*/
            Class.forName("com.microsoft.sqlserver.jdbc.SQLServerDriver");
            /*Establish a connection with the database*/
            try (Connection con =
DriverManager.getConnection("jdbc:sqlserver://sqlserver01;databaseName=Librar
y;user=user1;password=password#1234");)
            {
                /*Create a DatabaseMetaData object*/
                DatabaseMetaData dbmd = con.getMetaData();
                String[] tabTypes = {"TABLE"};
                /*Retrieve the names of database tables*/
                System.out.println("");
                System.out.println("Tables Names");
                System.out.println("-------------------");
                ResultSet tablesRS = dbmd.getTables(null, null, null,
tabTypes);
                while (tablesRS.next()) /*Display the names of database
tables*/
                {
                    System.out.println(tablesRS.getString("TABLE_NAME"));
                }
                        }
        }
```

```
            catch (Exception e)
            {
                System.out.println("Error : " + e);
            }
        }
    }
```

In the preceding code, a connection is established with the `Library` data source. The object of the `DatabaseMetaData` interface is declared using the `getMetaData()` method. The `DatabaseMetaData` object is used to retrieve the names of database tables using the `getTables()` method.

Using the ResultSetMetaData Interface

The `ResultSetMetaData` interface contains various methods that enable you to retrieve information about the data in a result set, such as numbers, names, and data types of the columns. The `ResultSet` interface provides the `getMetaData()` method to create an object of the `ResultSetMetaData` interface. You can use the following code snippet to create an object of the `ResultSetMetaData` interface:

```
ResultSetMetaData rm=rs.getMetaData();
```

In the preceding code snippet, `rs` refers to an object of the `ResultSet` interface. `rs` calls the `getMetaData()` method to create an object of the `ResultSetMetaData` interface.

The following table lists some commonly used methods of the `ResultSetMetaData` interface.

Method	***Description***
`int getColumnCount()`	*Returns an integer indicating the total number of columns in a `ResultSet` object.*
`String getColumnLabel(int column_index)`	*Retrieves the title of the table column corresponding to the specified index.*
`String getColumnName(int column_index)`	*Retrieves the name of the table column corresponding to the specified index.*
`int getColumnType(int column_index)`	*Retrieves the SQL data type of the table column corresponding to the specified index.*
`String getTableName(int column_index)`	*Retrieves the name of the database table that contains the column corresponding to the specified index.*
`boolean isAutoIncrement(int column_index)`	*Returns a `boolean` value that indicates whether the table column corresponding to the specified index increments automatically.*

Method	*Description*
`boolean isCaseSensitive(int column_index)`	*Returns a* `boolean` *value that indicates whether the table column corresponding to the specified index is case-sensitive.*
`boolean isReadOnly(int column_index)`	*Returns a* `boolean` *value that indicates whether the column in a* `ResultSet` *column corresponding to the specified index is read only.*
`boolean isWritable(int column_index)`	*Returns a* `boolean` *value that indicates whether the* `ResultSet` *column corresponding to the specified index is writeable.*

The Methods of the ResultSetMetaData Interface

Just a minute:

What are the metadata interfaces used to retrieve information about the database and the result set?

Answer:

The metadata interfaces used to retrieve information about the database and the result set are:

1. `DatabaseMetaData`
2. `ResultSetMetaData`

Activity 10.2: Creating an Application to Determine the Structure of a Table

Practice Questions

1. The _____ interface provides the methods that enable you to determine the properties of a database or RDBMS.

2. Identify the method of the `PreparedStatement` interface that sets the Java `byte` type value for the parameter corresponding to the specified index.
   a. `setByte(int index, byte val)`
   b. `setBytes(int index, byte[] val)`
   c. `setString(int index, String val)`
   d. `setShort(int index, short val)`

3. Why do you need to disable the auto-commit mode while working with batch updates?

4. Which is a standard way to call a stored procedure from RDBMS?

5. Which method of the `Connection` interface is used to create the `callableStatement` object?
   a. `prepareCall()`
   b. `getMetaData()`
   c. `prepareStatement()`
   d. `createStatement()`

Summary

In this chapter, you learned that:

- The `PreparedStatement` object allows you to pass runtime parameters to the SQL statements using the placeholders.
- There can be multiple placeholders in a single SQL statement. An index value is associated with each placeholder depending upon the position of the placeholder in the SQL statement.
- The placeholder stores the value assigned to it until the value is explicitly changed.
- A transaction is a set of one or more SQL statements executed as a single unit. A transaction is complete only when all the SQL statements in a transaction are successfully executed.
- If the `setAutoCommit()` method is set to `true`, the database operations performed by the SQL statements are automatically committed in the database.
- The `commit()` method reflects the changes made by the SQL statements permanently in the database.
- The `rollback()` method is used to undo the effect of all the SQL operations performed after the last commit operation.
- A batch is a group of update statements sent to a database to be executed as a single unit. You send the batch to a database as a single request using the same `Connection` object.
- The `executeBatch()` method returns an integer array that stores the update count for all the SQL statements that are executed successfully in a batch. The update count is the number of database rows affected by the database operation performed by each SQL statement.
- Batch update operations can throw two types of exceptions, `SQLException` and `BatchUpdateException`.
- `SQLException` is thrown when the database access problem occurs. `SQLException` is also thrown when a `SELECT` statement that returns a `ResultSet` object is executed in a batch.
- `BatchUpdateException` is thrown when the SQL statement in the batch cannot be executed due to the problem in accessing the specified table or presence of illegal arguments in the SQL statement.
- The `CallableStatement` interface contains various methods that enable you to call the stored procedures from a database.
- The parameters of a stored procedure can take any of the following three forms:
  - `IN`
  - `OUT`
  - `INOUT`
- Metadata is the information about data, such as the structure and properties of table.
- JDBC API provides two metadata interfaces to retrieve the information about the database and result set, `DatabaseMetaData` and `ResultSetMetaData`.
- The `DatabaseMetaData` interface declares the methods that enable you to determine the properties of a database.
- The `ResultSetMetaData` interface declares the methods that enable you to determine the information of a result set.

- The `getMetaData()` method of the `Connection` interface enables you to obtain the objects of the `DatabaseMetaData` interface. The methods in the `DatabaseMetaData` interface retrieve the information only about the database to which a Java application is connected.
- The `getMetaData()` method of the `ResultSet` interface enables you to create the instance of the `ResultSetMetaData` interface.

Glossary

A

Anonymous Inner Class

An anonymous inner class has no name, and it is either a subclass of a class or an implementer of an interface.

Atomic Operation

An atomic operation is an operation that is performed as a single unit. In addition, an atomic operation cannot be stopped in between by any other operations.

Atomic Variables

Atomic variables are the single variables on which operations, such as increment and decrement, are done in a single step.

Auto-commit

The auto-commit mode specifies that each SQL statement in a transaction is committed automatically as soon as the execution of the SQL statement completes.

B

Batch

A batch is a group of update statements sent to a database to be executed as a single unit.

Buffer

A buffer is a storage area in the memory that can be used for writing or reading data. As compared to streams, buffers can be used to provide faster I/O operations.

BufferedInputStream Class

The `BufferedInputStream` class is used to perform the read operations by using a temporary storage, buffer, in the memory.

BufferedOutputStream Class

The `BufferedOutputStream` class writes bytes to an output stream using a buffer for increased efficiency.

BufferedReader Class

The `BufferedReader` class is used to read the text from a character-input stream, such as a file, console, and array, while buffering characters.

BufferedWriter Class

The `BufferedWriter` class can be used to write text to an output stream.

C

Call Level Interface (CLI)

CLI is an interface consists of functions written in the C language to access databases.

Concurrency

Concurrency enables Java programmers to improve the efficiency and resource utilization of their applications by creating concurrent programs.

Cursor

Cursor enables you to move through the rows stored in the `ResultSet` object.

D

Data Source Information

Data Source Information contains the database information, such as the location of the database server, name of a database, user name, and password, to access a database server.

Deadlock

The deadlock condition arises in a computer system when two threads wait for each other to complete the operations before performing the individual action.

Doubly-linked List

The doubly-linked list is a set of sequentially linked records called nodes where each node contains two links that are the references of the previous node and the next node in the sequence, respectively.

Downcasting

Downcasting is usually done along the class hierarchy in a direction from the base class towards the derived classes.

E

Explicit Casting

Explicit casting occurs when one data type cannot be implicitly converted into another data type.

F

FileInputStream Class

The `FileInputStream` class is used to read data and the steams of bytes from the file.

FileOutputStream Class

The `FileOutputStream` class is used for writing data, byte by byte, to a file.

FileReader Class

The `FileReader` class is used for reading characters from a file, but it does not define any method of its own.

FileWriter Class

The `FileWriter` class writes character data to a file.

G

Generics

Generics mean parameterized types that enable you to write the code that can work with many types of object.

I

Implicit Casting

Implicit casting refers to an automatic conversion of one data type into another.

Inner Classes

Inner classes are the classes defined inside another class.

L

Lock Starvation

Lock starvation occurs when the execution of a thread is postponed because of its low priority.

M

Metadata

Metadata is the information about data, such as structure and properties of table.

Method-local Inner

A method-local inner is a class defined inside the method of the enclosing class.

O

Open Database Connectivity (ODBC)

ODBC is an open standard API to communicate with databases.

R

Regular Expressions

Regular expressions allow you to match a character sequence with another string.

Regular Inner Class

A regular inner class is a class whose definition appears inside the definition of another class.

S

Semaphore

A semaphore is a lock with an internal counter. It is used to restrict access to shared resources by multiple threads at the same time.

Static Inner Classes

Static inner classes are inner classes marked with the static modifier.

Symbolic Link

A symbolic link is a file that contains a reference to another target file or directory.

T

Task

A task is an object that implements the Runnable or Callable interface.

Thread

A thread can be defined as a single sequential flow of control within a program.

Thread priorities

Thread priorities are integers in the range of 1 to 10 that specify the priority of one thread with respect to the priority of another thread.

Type Inference

Type inference enables you to invoke the constructor of a generic class with an empty set of type parameters, <>.

Type Parameter

The type parameter section is represented by angular brackets, < >, that can have one or more types of parameters separated by commas.

U

Upcasting

Upcasting is usually done along the class hierarchy in a direction from the derived class to the base class.

X

XOPEN

The XOPEN error code is a standard message associated with an error that can identify the error across multiple databases.

Objectives Attainment Feedback

Programming in Java

Name: _____ Batch: _____ Date: _____

The objectives of this course are listed below. Please tick whether the objectives were achieved by you or not. Calculate the percentage at the end, fill in your name and batch details, and return the form to your coordinator.

S. No.	*Objectives*	*Yes*	*No*
1.	Explore UI components	☐	☐
2.	Manage layouts	☐	☐
3.	Explore Java event model	☐	☐
4.	Implement events	☐	☐
5.	Create inner classes	☐	☐
6.	Implement localization	☐	☐
7.	Create user-defined generic classes and methods	☐	☐
8.	Implement type-safety	☐	☐
9.	Use the Set interface	☐	☐
10.	Use the List interface	☐	☐
11.	Use the Map interface	☐	☐
12.	Use the Deque interface	☐	☐

S. No.	*Objectives*	*Yes*	*No*
13.	Implement sorting		
14.	Use threads in Java		
15.	Create threads		
16.	Implement thread synchronization		
17.	Implement concurrency		
18.	Get familiar with NIO		
19.	Perform the read and write operations on a file		
20.	Identify the layers in the JDBC architecture		
21.	Identify the types of JDBC drivers		
22.	Use JDBC API		
23.	Access Result Sets		
24.	Create applications using the PreparedStatement object		
25.	Manage database transactions		
26.	Implement batch updates in JDBC		
27.	Create and call stored procedures in JDBC		
28.	Use metadata in JDBC		
	Percentage: (# of Yes/28) * 100		

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