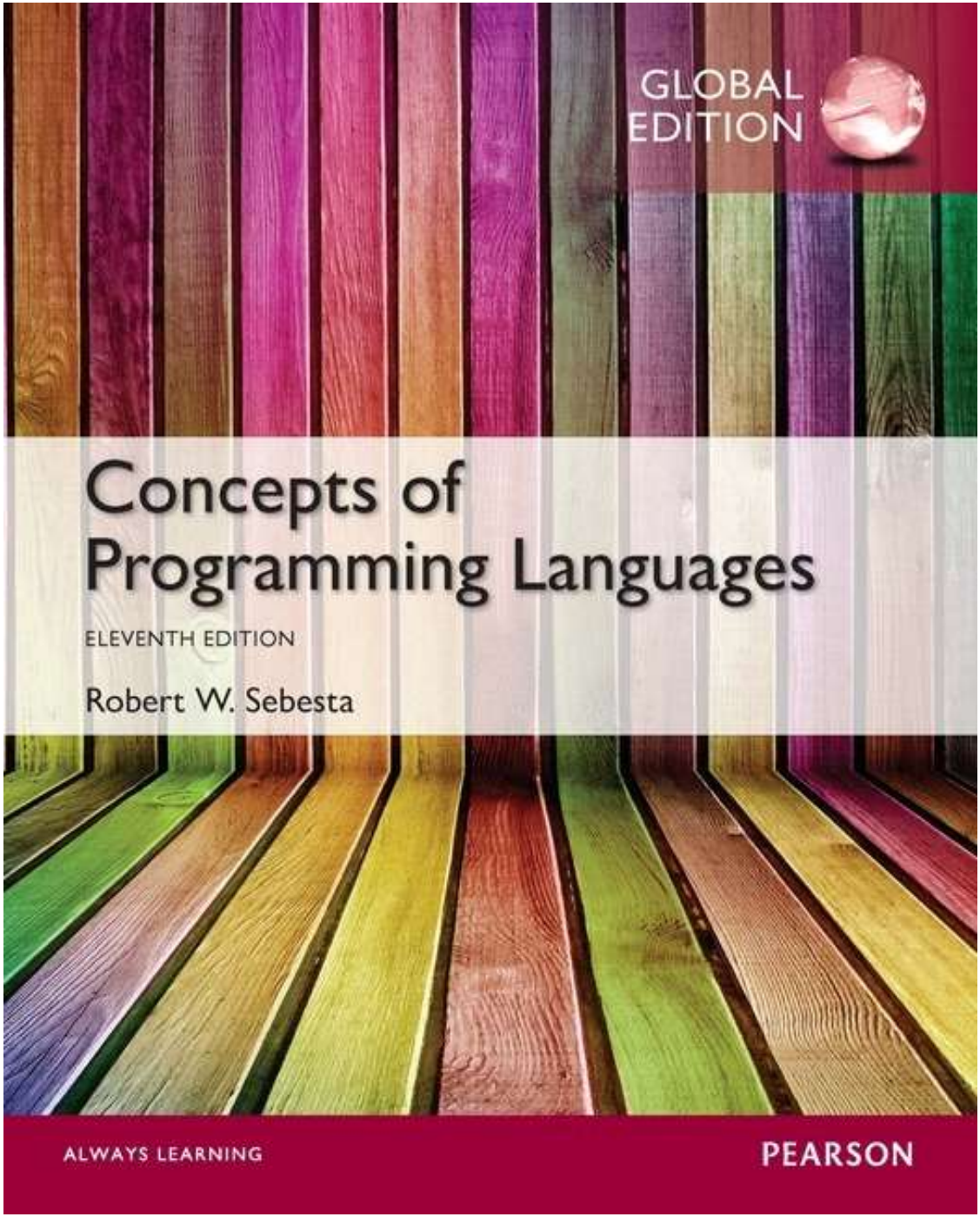
Chapter 14

Exception Handling and Event Handling



Chapter 14 Topics

- Introduction to Exception Handling
- Exception Handling in C++
- Exception Handling in Java
- Exception Handling in Python and Ruby
- Introduction to Event Handling
- Event Handling with Java
- Event Handling in C#

Introduction to Exception Handling

- In a language without exception handling
  - When an exception occurs, control goes to the operating system, where a message is displayed and the program is terminated
- In a language with exception handling
  - Programs are allowed to trap some exceptions, thereby providing the possibility of fixing the problem and continuing

Basic Concepts

- Many languages allow programs to trap input/output errors (including EOF)
- An *exception* is any unusual event, either erroneous or not, detectable by either hardware or software, that may require special processing
- The special processing that may be required after detection of an exception is called *exception handling*
- The exception handling code unit is called an *exception handler*

Exception Handling Alternatives

- An exception is raised when its associated event occurs
- A language that does not have exception handling capabilities can still define, detect, raise, and handle exceptions (user defined, software detected)
- Alternatives:
  - Send an auxiliary parameter or use the return value to indicate the return status of a subprogram
  - Pass a label parameter to all subprograms (error return is to the passed label)
  - Pass an exception handling subprogram to all subprograms

Advantages of Built-in Exception Handling

- Error detection code is tedious to write and it clutters the program
- Exception handling encourages programmers to consider many different possible errors
- Exception propagation allows a high level of reuse of exception handling code

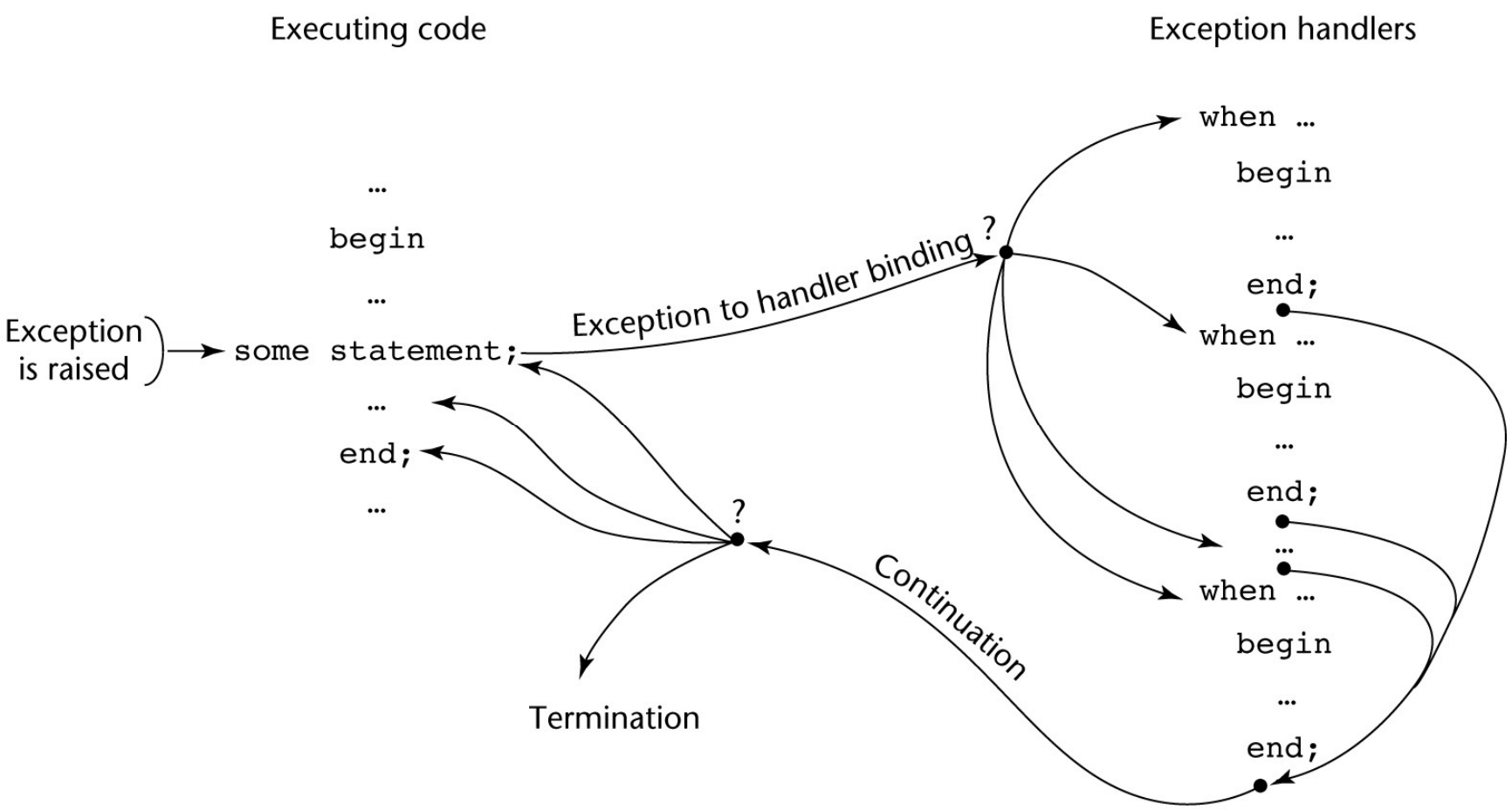
Design Issues

- How and where are exception handlers specified and what is their scope?
- How is an exception occurrence bound to an exception handler?
- Can information about the exception be passed to the handler?
- Where does execution continue, if at all, after an exception handler completes its execution? (continuation vs. resumption)
- Is some form of finalization provided?

Design Issues (continued)

- How are user-defined exceptions specified?
- Should there be default exception handlers for programs that do not provide their own?
- Can predefined exceptions be explicitly raised?
- Are hardware-detectable errors treated as exceptions that can be handled?
- Are there any predefined exceptions?
- How can exceptions be disabled, if at all?

Exception Handling Control Flow



Exception Handling in C++

- Added to C++ in 1990
- Design is based on that of CLU, Ada, and ML

C++ Exception Handlers

- Exception Handlers Form:

```
try {
-- code that is expected to raise an exception
}
catch (formal parameter) {
-- handler code
}
...
catch (formal parameter) {
-- handler code
}
```

The `catch` Function

- **`catch`** is the name of all handlers--it is an overloaded name, so the formal parameter of each must be unique
- The formal parameter need not have a variable
  - It can be simply a type name to distinguish the handler it is in from others
- The formal parameter can be used to transfer information to the handler
- The formal parameter can be an ellipsis, in which case it handles all exceptions not yet handled

Throwing Exceptions

- Exceptions are all raised explicitly by the statement:

  `throw` [*expression*] **`;`**

- The brackets are metasymbols
- A **`throw`** without an operand can only appear in a handler; when it appears, it simply re-raises the exception, which is then handled elsewhere
- The type of the expression disambiguates the intended handler

Unhandled Exceptions

- An unhandled exception is propagated to the caller of the function in which it is raised
- This propagation continues to the main function
- If no handler is found, the default handler is called

Continuation

- After a handler completes its execution, control flows to the first statement after the last handler in the sequence of handlers of which it is an element
- Other design choices
  - All exceptions are user-defined
  - Exceptions are neither specified nor declared
  - The default handler, `unexpected`, simply terminates the program; `unexpected` can be redefined by the user
  - Functions can list the exceptions they may raise
  - Without a specification, a function can raise any exception (the **`throw`** clause)

Evaluation

- There are no predefined exceptions
- It is odd that exceptions are not named and that hardware- and system software-detectable exceptions cannot be handled
- Binding exceptions to handlers through the type of the parameter certainly does not promote readability

Exception Handling in Java

- Based on that of C++, but more in line with OOP philosophy
- All exceptions are objects of classes that are descendants of the `Throwable` class

Classes of Exceptions

- The Java library includes two subclasses of `Throwable`:
  - `Error`
    - Thrown by the Java interpreter for events such as heap overflow
    - Never handled by user programs
  - `Exception`
    - User-defined exceptions are usually subclasses of this
    - Has two predefined subclasses, `IOException` and `RuntimeException` (e.g., `ArrayIndexOutOfBoundsException` and `NullPointerException`

Java Exception Handlers

- Like those of C++, except every **`catch`** requires a named parameter and all parameters must be descendants of `Throwable`
- Syntax of **`try`** clause is exactly that of C++
- Exceptions are thrown with **`throw`**, as in C++, but often the **`throw`** includes the **`new`** operator to create the object, as in:

```
throw new MyException();
```

Binding Exceptions to Handlers

- Binding an exception to a handler is simpler in Java than it is in C++
  - An exception is bound to the first handler with a parameter is the same class as the thrown object or an ancestor of it
- An exception can be handled and rethrown by including a **`throw`** in the handler (a handler could also throw a different exception)

Continuation

- If no handler is found in the **`try`** construct, the search is continued in the nearest enclosing **`try`** construct, etc.
- If no handler is found in the method, the exception is propagated to the method's caller
- If no handler is found (all the way to `main`), the program is terminated
- To insure that all exceptions are caught, a handler can be included in any **`try`** construct that catches all exceptions
  - Simply use an `Exception` class parameter
  - Of course, it must be the last in the **`try`** construct

Checked and Unchecked Exceptions

- The Java **`throws`** clause is quite different from the **`throw`** clause of C++
- Exceptions of class `Error` and `RunTimeException` and all of their descendants are called unchecked exceptions; all other exceptions are called checked exceptions
- Checked exceptions that may be thrown by a method must be either:
  - Listed in the **`throws`** clause, or
  - Handled in the method

Other Design Choices

- A method cannot declare more exceptions in its **`throws`** clause than the method it overrides
- A method that calls a method that lists a particular checked exception in its **`throws`** clause has three alternatives for dealing with that exception:
  - Catch and handle the exception
  - Catch the exception and throw an exception that is listed in its own **`throws`** clause
  - Declare it in its **`throws`** clause and do not handle it

The `finally` Clause

- Can appear at the end of a try construct
- Form:

```
finally {
...
}
```

- Purpose: To specify code that is to be executed, regardless of what happens in the `try` construct

Example

- A try construct with a finally clause can be used outside exception handling

```
try {
    for (index = 0; index < 100; index++) {
            ...
            if (...) {
                return;
            }  //** end of if
}  //** end of try clause
finally {
    ...
}  //** end of try construct
```

Assertions

- Statements in the program declaring a boolean expression regarding the current state of the computation
- When evaluated to true nothing happens
- When evaluated to false an `AssertionError` exception is thrown
- Can be disabled during runtime without program modification or recompilation
- Two forms
  - **`assert`** *condition*;
  - **`assert`** *condition*: *expression*;

Evaluation

- The types of exceptions makes more sense than in the case of C++
- The **`throws`** clause is better than that of C++ (The **`throw`** clause in C++ says little to the programmer)
- The **`finally`** clause is often useful
- The Java interpreter throws a variety of exceptions that can be handled by user programs

Exception Handling in Python

- Exceptions are objects; the base class is `BaseException`
- All predefined and user-defined exceptions are derived from `Exception`
- Predefined subclasses of `Exception` are `ArithmeticError` (subclasses are `OverflowError`, `ZeroDivisionError`, and `FloatingPointError`) and `LookupError` (subclasses are `IndexError` and `KeyError`)

Exception Handling in Python (continued)

```
try:
   - The try block
except Exception1:
   - Handler for Exception1
except Exception2:
   - Handler for Exception2
...
else:
   - The else block (no exception is raised)
finally:
   - the finally block (do it no matter what)
```

Exception Handling in Python (continued)

- Handlers handle the named exception plus all subclasses of that exception, so if the named exception is `Exception`, it handlers all predefined and user-defined exceptions
- Unhandled exceptions are propagated to the nearest enclosing try block; if no handler is found, the default handler is called
- `Raise IndexError` creates an instance
- The raised exception object can be gotten:

```
except Exception as ex_obj:
```

Exception Handling in Python (continued)

- The `assert` statement tests its Boolean expression (first parameter) and sends its second parameter to the constructor for the exception object to be raised

```
assert test, data
```

Exception Handling in Ruby

- Exceptions are objects
- There are many predefined exceptions
- All exceptions that are user handled are either `StandardError` class or a subclass of it
- `StandardError` is derived from `Exception`, which has two methods, `message` and `backtrace`
- Exceptions can be raised with **`raise`**, which often has the form:

```
raise "bad parameter" if count == 0
```

Exception Handling in Ruby (continued)

- Handlers are placed at the end of a begin–end block of code; introduced by `rescue`

  `begin`

  – Statements in the block

  `rescue`

  – Handler

  `end`

- The block could include `else` and/or `ensure` clauses, which are like `else` and `finally` in Java

Exception Handling in Ruby (continued)

- Unlike the other languages we have discussed, in Ruby the code that raised an exception can be rerun by placing a `retry` statement at the end of the handler

Introduction to Event Handling

- An *event* is a notification that something specific has occurred, such as a mouse click on a graphical button
- The *event handler* is a segment of code that is executed in response to an event

Java Swing GUI Components

- Text box is an object of class `JTextField`
- Radio button is an object of class `JRadioButton`
- Applet's display is a frame, a multilayered structure
- Content pane is one layer, where applets put output
- GUI components can be placed in a frame
- Layout manager objects are used to control the placement of components

The Java Event Model

- User interactions with GUI components create events that can be caught by event handlers, called *event listeners*
- An event generator tells a listener of an event by sending a message
- An interface is used to make event-handling methods conform to a standard protocol
- A class that implements a listener must implement an interface for the listener

The Java Event Model (continued)

- One class of events is `ItemEvent`, which is associated with the event of clicking a checkbox, a radio button, or a list item
- The `ItemListener` interface prescribes a method, `itemStateChanged`, which is a handler for `ItemEvent` events
- The listener is created with `addItemListener`

Event Handling in C#

- Event handling in C# (and the other .NET languages) is similar to that in Java
- .NET has two approaches, Windows Forms and Windows Presentation Foundation—we cover only the former (which is the original approach)
- An application subclasses the `Form` predefined class (defined in `System.Windows.Forms`)
- There is no need to create a frame or panel in which to place the GUI components
- `Label` objects are used to place text in the window
- Radio buttons are objects of the `RadioButton` class

Event Handling in C# (continued)

- Components are positioned by assigning a new `Point` object to the Location property of the component

```
private RadioButton plain = new RadioButton();
plain.Location = new Point(100, 300);
plain.Text = "Plain";
controls.Add(plain);
```

- All C# event handlers have the same protocol, the return type is **`void`** and the two parameters are of types **`object`** and `EventArgs`

Event Handling in C# (continued)

- An event handler can have any name
- A radio button is tested with the Boolean Checked property of the button

```
private void rb_CheckedChanged (object o,
                                EventArgs e) {
  if (plain.Checked) …
  ...
}
```

- To register an event, a new `EventHandler` object must be created and added to the predefined delegate for the event

Event Handling in C# (continued)

- When a radio button changes from unchecked to checked, the `CheckedChanged` event is raised
- The associated delegate is referenced by the name of the event
- If the handler was named `rb_CheckedChanged`, we could register it on the radio button named `plain` with:

```
plain.CheckedChanged +=
    new EventHandler (rb_CheckedChanged);
```

Summary

- Ada provides extensive exception-handling facilities with a comprehensive set of built-in exceptions.
- C++ includes no predefined exceptions
- Exceptions are bound to handlers by connecting the type of expression in the **`throw`** statement to that of the formal parameter of the **`catch`** function
- Java exceptions are similar to C++ exceptions except that a Java exception must be a descendant of the `Throwable` class. Additionally Java includes a **`finally`** clause
- An event is a notification that something has occurred that requires handling by an event handler
- Java event handling is defined on the Swing components
- C# event handling is the .NET model, which is similar to the Java model