

Exceptions



EECS2030 B & E: Advanced
Object Oriented Programming
Fall 2021

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Learning Outcomes

This module is designed to help you learn about:

- Caller vs. Callee in a Method Invocation
- **Error Handling** via Console Message
- The **Catch**-or-**Specify** Requirement
- Example: To Handle or Not to Handle?
- **Error Handling** via Exceptions
- What to Do When an Exception is Thrown at Runtime
- More Examples on Exception Handling

Caller vs. Callee

- Within the body implementation of a method (`{...}`), we may call other methods.

```
1 class C1 {  
2     void m1() {  
3         C2 o = new C2();  
4         o.m2(); /* static type of o is C2 */  
5     }  
6 }
```

- From **Line 4**, we say:
 - Method **C1.m1** (i.e., method `m1` from class `C1`) is the **caller** of method **C2.m2**.
 - Method **C2.m2** is the **callee** of method **C1.m1**.

Stack of Method Calls

- Execution of a Java project *starts* from the *main method* of some class (e.g., `CircleTester`, `BankApplication`).
- Each line of *method call* involves the execution of that method's *body implementation*
 - That method's body implementation may also involve *method calls*, which may in turn involve more *method calls*, and *etc.*
 - It is typical that we end up with *a chain of method calls* !
 - We visualize this chain of method calls as a *call stack* .
For example:
 - `Account.withdraw` [top of stack; latest called]
 - `Bank.withdrawFrom`
 - `BankApplication.main` [bottom of stack; earliest called]
 - The closer a method is to the *top* of the call stack, the *later* its call was made.

Error Reporting via Consoles: Circles (1)

```
1 class Circle {
2     double radius;
3     Circle() { /* radius defaults to 0 */ }
4     void setRadius(double r) {
5         if ( r < 0 ) { System.out.println( "Invalid radius." ); }
6         else { radius = r; }
7     }
8     double getArea() { return radius * radius * 3.14; }
9 }
```

- A negative radius is considered as an *invalid input value* to method `setRadius`.
- What if the **caller** of `Circle.setRadius` passes a negative value for `r`?
 - An error message is *printed to the console* (Line 5) to warn the **caller** of `setRadius`.
 - However, printing an error message to the console *does not force* the **caller** of `setRadius` to stop and handle invalid values of `r`.

Error Reporting via Consoles: Circles (2)

```
1 class CircleCalculator {
2     public static void main(String[] args) {
3         Circle c = new Circle();
4         c.setRadius(-10);
5         double area = c.getArea();
6         System.out.println("Area: " + area);
7     }
8 }
```

- **L4:** `CircleCalculator.main` is **caller** of `Circle.setRadius`
- A negative radius is passed to `setRadius` in **Line 4**.
- The execution *always flows smoothly* from **Lines 4** to **Line 5**, *even when there was an error* message printed from **Line 4**.
- It is not feasible to check if there is any kind of error message printed to the console right after the execution of **Line 4**.
- **Solution:** A way to force `CircleCalculator.main`, **caller** of `Circle.setRadius`, to realize that things might go wrong.
⇒ When things do go wrong, immediate actions are needed.

Error Reporting via Consoles: Bank (1)

```
class Account {
    int id; double balance;
    Account(int id) { this.id = id; /* balance defaults to 0 */ }
    void deposit(double a) {
        if (a < 0) { System.out.println("Invalid deposit."); }
        else { balance += a; }
    }
    void withdraw(double a) {
        if (a < 0 || balance - a < 0) {
            System.out.println("Invalid withdraw."); }
        else { balance -= a; }
    }
}
```

- A negative deposit or withdraw amount is *invalid*.
- When an *error* occurs, a message is *printed to the console*.
- However, printing error messages does not force the **caller** of `Account.deposit` or `Account.withdraw` to stop and handle invalid values of `a`.

Error Reporting via Consoles: Bank (2)

```
1 class Bank {
2     Account[] accounts; int numberOfAccounts;
3     Account(int id) { ... }
4     void withdrawFrom(int id, double a) {
5         for(int i = 0; i < numberOfAccounts; i++) {
6             if(accounts[i].id == id) {
7                 accounts[i].withdraw(a);
8             }
9         } /* end for */
10    } /* end withdraw */
11 }
```

- L7: `Bank.withdrawFrom` is **caller** of `Account.withdraw`
- What if in **Line 7** the value of `a` is negative?
Error message `Invalid withdraw` printed from method `Account.withdraw` to console.
- Impossible to force `Bank.withdrawFrom`, the **caller** of `Account.withdraw`, to stop and handle invalid values of `a`.

Error Reporting via Consoles: Bank (3)

```
1 class BankApplication {
2     public static void main(String[] args) {
3         Scanner input = new Scanner(System.in);
4         Bank b = new Bank(); Account ac1 = new Account(23);
5         b.addAccount(ac1);
6         double a = input.nextDouble();
7         b.withdrawFrom(23, a);
8         System.out.println("Transaction Completed.");
9     }
```

- There is a chain of method calls:
 - **BankApplication.main** calls **Bank.withdrawFrom**
 - **Bank.withdrawFrom** calls **Account.withdraw**.
- The actual update of balance occurs at the `Account` class.
 - What if in **Line 7** the value of `a` is negative?
Invalid withdraw printed from **Bank.withdrawFrom**, originated from **Account.withdraw** to console.
 - However, impossible to stop **BankApplication.main** from continuing to execute **Line 8**, printing Transaction Completed.
- **Solution:** Define error checking only once and let it *propagate*.

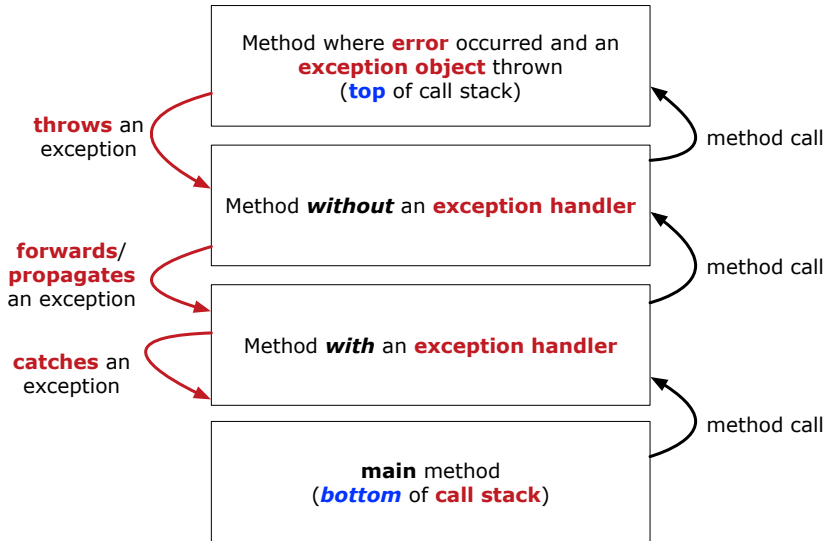
What is an Exception?

- An **exception** is an *event*, which
 - occurs during the *execution of a program*
 - *disrupts the normal flow* of the program's instructions
- When an error occurs within a method:
 - the method throws an exception:
 - first creates an *exception object*
 - then hands it over to the *runtime system*
 - the exception object contains information about the error:
 - type [e.g., `NegativeRadiusException`]
 - the state of the program when the error occurred

What to Do When an Exception Is Thrown? (1)

- After a method *throws an exception*, the *runtime system* searches the corresponding **call stack** for a method that contains a block of code to *handle* the exception.
 - This block of code is called an **exception handler**.
 - An exception handler is **appropriate** if the *type* of the *exception object thrown* matches the *type* that can be handled by the handler.
 - The exception handler chosen is said to *catch* the exception.
 - The search goes from the *top* to the *bottom* of the call stack:
 - The method in which the *error* occurred is searched first.
 - The *exception handler* is not found in the current method being searched ⇒ Search the method that calls the current method, and *etc.*
 - When an appropriate *handler* is found, the *runtime system* passes the exception to the handler.
 - The *runtime system* searches all the methods on the **call stack** without finding an **appropriate exception handler**
 ⇒ The program terminates and the exception object is directly “thrown” to the console!

What to Do When an Exception Is Thrown? (2)



The Catch or Specify Requirement (1)

Code (e.g., a method call) that might throw certain exceptions must be enclosed by one of the two ways:

1. The “Catch” Solution: A `try` statement that *catches* and *handles* the *exception* (without propagating that exception to the method's *caller*).

```
main(...) {  
    Circle c = new Circle();  
    try {  
        c.setRadius(-10);  
    }  
    catch (NegativeRadiusException e) {  
        ...  
    }  
}
```

The Catch or Specify Requirement (2)

Code (e.g., a method call) that might throw certain exceptions must be enclosed by one of the two ways:

2. The “Specify” Solution: A method that specifies as part of its **header** that it may (or may not) **throw** the **exception** (which will be thrown to the method’s **caller** for handling).

```
class Bank {
    Account[] accounts; /* attribute */
    void withdraw (double amount)
        throws InvalidTransactionException {
        ...
        accounts[i].withdraw(amount);
        ...
    }
}
```

Example: to Handle or Not to Handle? (1.1)

Consider the following three classes:

```
class A {
    ma(int i) {
        if(i < 0) { /* Error */ }
        else { /* Do something. */ }
    }
}
```

```
class B {
    mb(int i) {
        A oa = new A();
        oa.ma(i); /* Error occurs if i < 0 */
    }
}
```

```
class Tester {
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        int i = input.nextInt();
        B ob = new B();
        ob.mb(i); /* Where can the error be handled? */
    }
}
```

Example: to Handle or Not to Handle? (1.2)

- We assume the following kind of error for negative values:

```
class NegValException extends Exception {  
    NegValException(String s) { super(s); }  
}
```

- The above kind of exception may be thrown by calling `A.ma`.
- We will see three kinds of possibilities of handling this exception:

Version 1:

Handle it in `B.mb`

Version 2:

Pass it from `B.mb` and handle it in `Tester.main`

Version 3:

Pass it from `B.mb`, then from `Tester.main`, then throw it to the console.

Example: to Handle or Not to Handle? (2.1)

Version 1: Handle the exception in B.mb.

```
class A {  
    ma(int i) throws NegValException {  
        if(i < 0) { throw new NegValException("Error."); }  
        else { /* Do something. */ }  
    } }  

```

```
class B {  
    mb(int i) {  
        A oa = new A();  
        try { oa.ma(i); }  
        catch(NegValException nve) { /* Do something. */ }  
    } }  

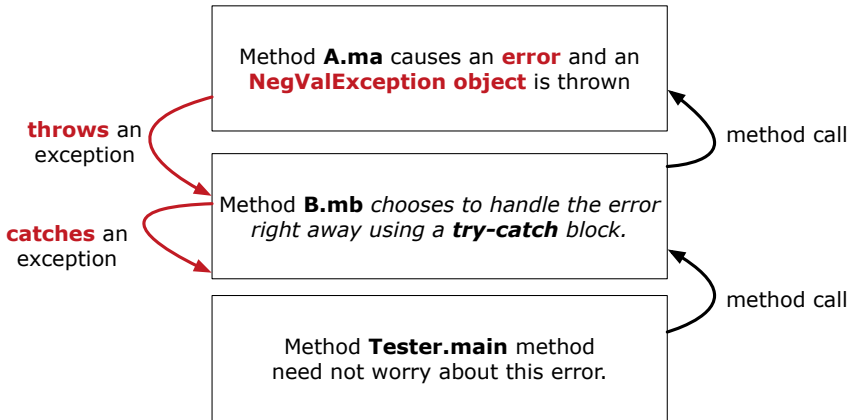
```

```
class Tester {  
    public static void main(String[] args) {  
        Scanner input = new Scanner(System.in);  
        int i = input.nextInt();  
        B ob = new B();  
        ob.mb(i); /* Error, if any, would have been handled in B.mb. */  
    } }  

```

Example: to Handle or Not to Handle? (2.2)

Version 1: Handle the exception in B.mb.



Example: to Handle or Not to Handle? (3.1)

Version 2: Handle the exception in `Tester.main`.

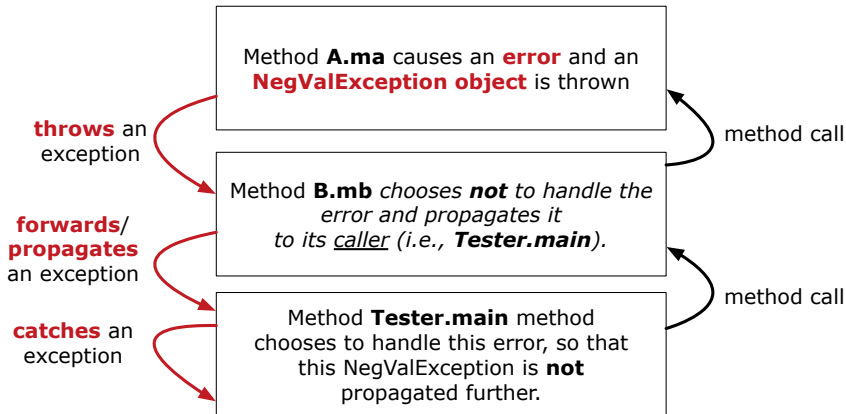
```
class A {  
    ma(int i) throws NegValException {  
        if(i < 0) { throw new NegValException("Error."); }  
        else { /* Do something. */ }  
    } }  
}
```

```
class B {  
    mb(int i) throws NegValException {  
        A oa = new A();  
        oa.ma(i);  
    } }  
}
```

```
class Tester {  
    public static void main(String[] args) {  
        Scanner input = new Scanner(System.in);  
        int i = input.nextInt();  
        B ob = new B();  
        try { ob.mb(i); }  
        catch(NegValException nve) { /* Do something. */ }  
    } }  
}
```

Example: to Handle or Not to Handle? (3.2)

Version 2: Handle the exception in `Tester.main`.



Example: to Handle or Not to Handle? (4.1)

Version 3: Handle in neither of the classes.

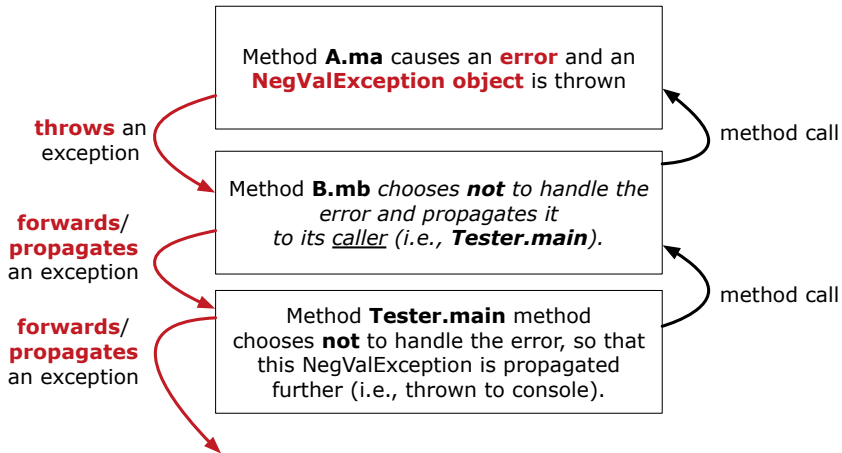
```
class A {  
    ma(int i) throws NegValException {  
        if(i < 0) { throw new NegValException("Error."); }  
        else { /* Do something. */ }  
    }  
}
```

```
class B {  
    mb(int i) throws NegValException {  
        A oa = new A();  
        oa.ma(i);  
    }  
}
```

```
class Tester {  
    public static void main(String[] args) throws NegValException {  
        Scanner input = new Scanner(System.in);  
        int i = input.nextInt();  
        B ob = new B();  
        ob.mb(i);  
    }  
}
```

Example: to Handle or Not to Handle? (4.2)

Version 3: Handle in neither of the classes.



Error Reporting via Exceptions: Circles (1)

```
public class InvalidRadiusException extends Exception {  
    public InvalidRadiusException(String s) {  
        super(s);  
    }  
}
```

- A new kind of `Exception`: `InvalidRadiusException`
- For any method that can have this kind of error, we declare at that method's *header* that it may *throw* an `InvalidRadiusException` object.

Error Reporting via Exceptions: Circles (2)

```
class Circle {
    double radius;
    Circle() { /* radius defaults to 0 */ }
    void setRadius(double r) throws InvalidRadiusException {
        if (r < 0) {
            throw new InvalidRadiusException("Negative radius.");
        }
        else { radius = r; }
    }
    double getArea() { return radius * radius * 3.14; }
}
```

- As part of the *header* of `setRadius`, we declare that it may *throw* an `InvalidRadiusException` object at runtime.
- Any method that calls `setRadius` will be forced to *deal with this potential error*.

Error Reporting via Exceptions: Circles (3)

```
1 class CircleCalculator1 {
2     public static void main(String[] args) {
3         Circle c = new Circle();
4         try {
5             c.setRadius(-10);
6             double area = c.getArea();
7             System.out.println("Area: " + area);
8         }
9         catch(InvalidRadiusException e) {
10            System.out.println(e);
11        }
12    } }
```

- **Lines 6** is forced to be wrapped within a **try-catch** block, since it may *throw* an `InvalidRadiusException` object.
- If an `InvalidRadiusException` object is thrown from **Line 6**, then the normal flow of execution is *interrupted* and we go to the `catch` block starting from **Line 9**.

Error Reporting via Exceptions: Circles (4)

Exercise: Extend `CircleCalculator1`: repeatedly prompt for a new radius value until a valid one is entered (i.e., the `InvalidRadiusException` does not occur).

```
Enter a radius:
```

```
-5
```

```
Radius -5.0 is invalid, try again!
```

```
Enter a radius:
```

```
-1
```

```
Radius -1.0 is invalid, try again!
```

```
Enter a radius:
```

```
5
```

```
Circle with radius 5.0 has area: 78.5
```

Error Reporting via Exceptions: Circles (5)

```
1 public class CircleCalculator2 {
2     public static void main(String[] args) {
3         Scanner input = new Scanner(System.in);
4         boolean inputRadiusIsValid = false;
5         while(!inputRadiusIsValid) {
6             System.out.println("Enter a radius:");
7             double r = input.nextDouble();
8             Circle c = new Circle();
9             try { c.setRadius(r);
10                inputRadiusIsValid = true;
11                System.out.print("Circle with radius " + r);
12                System.out.println(" has area: " + c.getArea()); }
13             catch(InvalidRadiusException e) { print("Try again!"); }
14         } } }
```

- At L7, if the user's input value is:
 - Non-Negative: L8 – L12. [inputRadiusIsValid set **true**]
 - Negative: L8, L9, L13. [inputRadiusIsValid remains **false**]

Error Reporting via Exceptions: Bank (1)

```
public class InvalidTransactionException extends Exception {  
    public InvalidTransactionException(String s) {  
        super(s);  
    }  
}
```

- A new kind of Exception:
InvalidTransactionException
- For any method that can have this kind of error, we declare at that method's *header* that it may *throw* an InvalidTransactionException object.

Error Reporting via Exceptions: Bank (2)

```
class Account {
    int id; double balance;
    Account() { /* balance defaults to 0 */ }
    void withdraw(double a) throws InvalidTransactionException {
        if (a < 0 || balance - a < 0) {
            throw new InvalidTransactionException("Invalid withdraw.");
        } else { balance -= a; }
    }
}
```

- As part of the *header* of `withdraw`, we declare that it may *throw* an `InvalidTransactionException` object at runtime.
- Any method that calls `withdraw` will be forced to *deal with this potential error*.

Error Reporting via Exceptions: Bank (3)

```
class Bank {
    Account[] accounts; int numberOfAccounts;
    Account(int id) { ... }
    void withdraw(int id, double a)
        throws InvalidTransactionException {
        for(int i = 0; i < numberOfAccounts; i++) {
            if(accounts[i].id == id) {
                accounts[i].withdraw(a);
            }
        } /* end for */ } /* end withdraw */ }
```

- As part of the *header* of `withdraw`, we declare that it may *throw* an `InvalidTransactionException` object.
- Any method that calls `withdraw` will be forced to *deal with this potential error*.
- We are *propagating* the potential error for the right party (i.e., `BankApplication`) to handle.

Error Reporting via Exceptions: Bank (4)

```
1 class BankApplication {
2     public static void main(String[] args) {
3         Bank b = new Bank();
4         Account accl = new Account(23);
5         b.addAccount(accl);
6         Scanner input = new Scanner(System.in);
7         double a = input.nextDouble();
8         try {
9             b.withdraw(23, a);
10            System.out.println(accl.balance); }
11        catch (InvalidTransactionException e) {
12            System.out.println(e); } } }
```

- **Lines 9** is forced to be wrapped within a **try-catch** block, since it may **throw** an `InvalidTransactionException` object.
- If an `InvalidTransactionException` object is thrown from **Line 9**, then the normal flow of execution is interrupted and we go to the `catch` block starting from **Line 11**.

More Examples (1)

```
double r = ...;
double a = ...;
try{
    Bank b = new Bank();
    b.addAccount(new Account(34));
    b.deposit(34, 100);
    b.withdraw(34, a);
    Circle c = new Circle();
    c.setRadius(r);
    System.out.println(r.getArea());
}
catch(NegativeRadiusException e) {
    System.out.println(r + " is not a valid radius value.");
    e.printStackTrace();
}
catch(InvalidTransactionException e) {
    System.out.println(r + " is not a valid transaction value.");
    e.printStackTrace();
}
```


More Example (2.1)

The `Integer` class supports a method for parsing Strings:

```
public static int parseInt(String s)
                    throws NumberFormatException
```

e.g., `Integer.parseInt("23")` returns 23

e.g., `Integer.parseInt("twenty-three")` throws a `NumberFormatException`

Write a fragment of code that prompts the user to enter a string (using `nextLine` from `Scanner`) that represents an integer.

If the user input is not a valid integer, then prompt them to enter again.

More Example (2.2)

```
Scanner input = new Scanner(System.in);
boolean validInteger = false;
while (!validInteger) {
    System.out.println("Enter an integer:");
    String userInput = input.nextLine();
    try {
        int userInteger = Integer.parseInt(userInput);
        validInteger = true;
    }
    catch (NumberFormatException e) {
        System.out.println(userInput + " is not a valid integer.");
        /* validInteger remains false */
    }
}
```

Beyond this lecture...

- Practice creating a new *exception* class upon a method throwing it in the body of implementation (e.g., `InvalidRadiusException`, `InvalidTransactionException`).
- Play with the source code:
 - `ExceptionsCircleAndBank.zip`
 - `ExceptionsToHandleOrNotToHandle.zip`

Tip. Change input values so as to explore, in Eclipse *debugger*, possible (*normal* vs. *abnormal*) **execution paths**.

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Learning Outcomes

Caller vs. Callee

Stack of Method Calls

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What is an Exception?

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The Catch or Specify Requirement (2)

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More Examples (1)

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More Example (2.2)

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Beyond this lecture...