Exceptions

EECS2030 B: Advanced Object Oriented Programming
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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***.

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   pubic static void main(String[] args) {
3     Scanner input = new Scanner(System.in);
4     Bank b = new Bank(); Account acc1 = new Account(23);
5     b.addAccount(acc1);
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`, printed from `Account.withdraw` to console.
  - However, impossible to stop `BankApplication.main` from continuing to executed **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

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*.

```
main(...) {
  Circle c = new Circle();
  try {
    c.setRadius(-10);
  }
  catch(NegativeRaidusException 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 *signature* that it *can throw* the exception (without handling that exception).

```
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`.

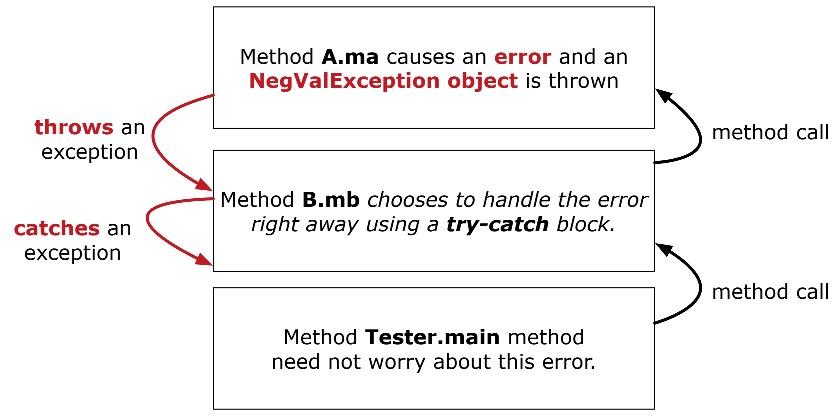
```
class A {
  ma(int i) throws NegValException {
    if(i < 0) { throw new NegValException("Error."); }
    else { /* Do something. */ }
  } }
```

```
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`.


Method **A.ma** causes an **error** and an **NegValException object** is thrown

Method **B.mb** *chooses to handle the error right away using a **try-catch** block.*

Method **Tester.main** method need not worry about this error.

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

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

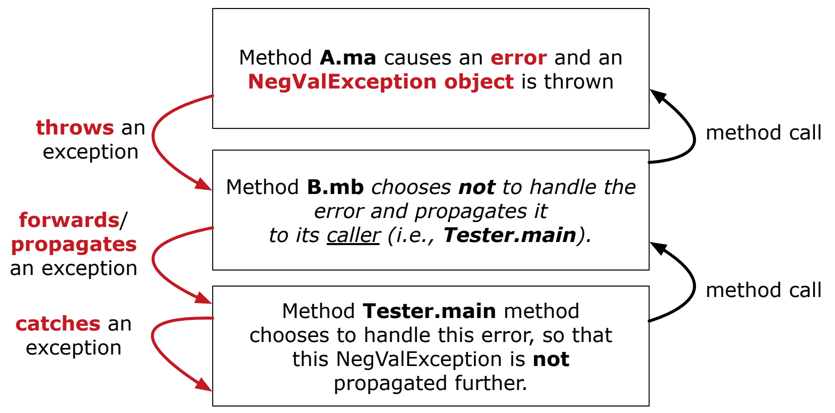
```
class A {
  ma(int i) throws NegValException {
    if(i < 0) { throw new NegValException("Error."); }
    else { /* Do something. */ }
  } }
```

```
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`.


Method **A.ma** causes an **error** and an **NegValException object** is thrown

Method **B.mb** *chooses **not** to handle the error and propagates it to its caller (i.e., **Tester.main**).*

Method **Tester.main** method chooses to handle this error, so that this NegValException is **not** propagated further.

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

Version 3: Handle in neither of the classes.

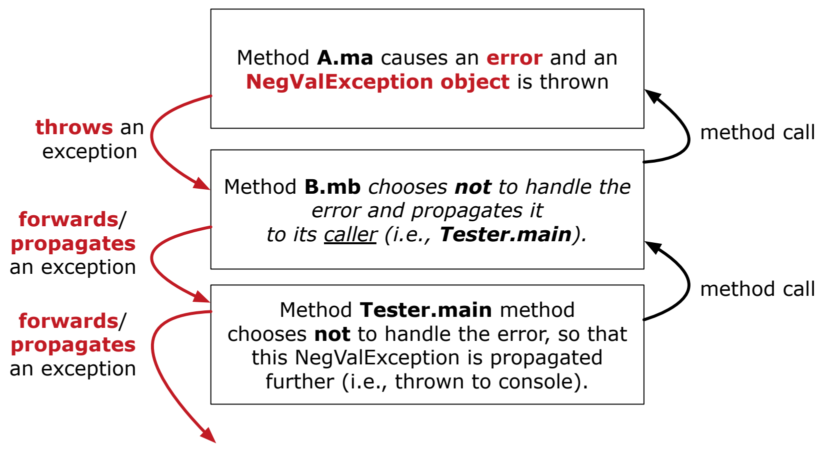
```
class A {
  ma(int i) throws NegValException {
    if(i < 0) { throw new NegValException("Error."); }
    else { /* Do something. */ }
  } }
```

```
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.


Method A.ma causes an error and an NegValException object is thrown
throws an exception
method call
Method B.mb chooses not to handle the error and propagates it to its caller (i.e., Tester.main).
forwards/ propagates an exception
method call
Method Tester.main method chooses not to handle the error, so that this NegValException is propagated further (i.e., thrown to console).
forwards/ propagates an exception

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 *signature* that it may *throw* an `InvalidRaidusException` 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 *signature* 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 *signature* 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 *signature* 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 *signature* 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)

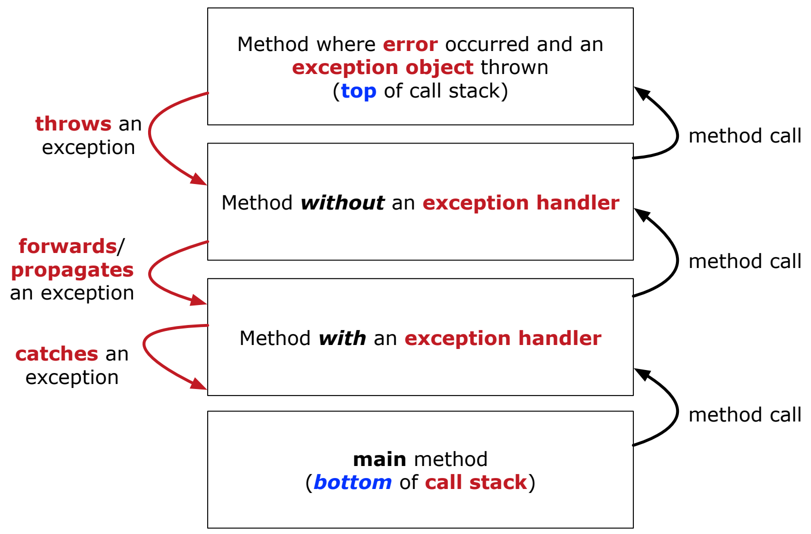
```
1   class BankApplication {
2    pubic static void main(String[] args) {
3      Bank b = new Bank();
4      Account acc1 = new Account(23);
5      b.addAccount(acc1);
6      Scanner input = new Scanner(System.in);
7      double a = input.nextDouble();
8      try {
9        b.withdraw(23, a);
10       System.out.println(acc1.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**.

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 call this chain of method calls 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.

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


Method where error occurred and an exception object thrown (top of call stack)
throws an exception
method call
Method without an exception handler
forwards/ propagates an exception
method call
Method with an exception handler
catches an exception
method call
main method (bottom of call stack)

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

- 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!

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 */
  }
}
```

Index (1)

Index (2)

Index (3)