CS1092: Object-Oriented Programming with Java
More on EXCEPTIONS

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Supporting and Background Material

- Copies of key slides (already handed out)
- Chapter 17 of the JTL book (follows this presentation) — lecture notes
- Recommended reading books for course
  - Chapter 8 (8.2) of Savitch "JAVA: An introduction to Computer Science and Programming", 3rd Edition
  - Chapter 13 (13.2, 13.5, 13.7) of Liang "Introduction to JAVA Programming", International Edition

Outline

Exception Classes
- Review
- Inheritance in Action
- Custom Exceptions
- The Notional Lottery with Exceptions
- Summary

Brief Recap

- Run-time errors are instances of the `Exception` class
- Exceptions can be captured by `try ... catch ...` statement blocks
- There can be multiple `catch` blocks
- Exceptions can be explicitly thrown by the `throw` statement
- Exceptions in GUIs: an unhandled exception in a GUI event thread doesn't terminate the main application
- Methods declare exceptions that are not handled within the method
- The invoking method of a method that declares an exception is thrown must either declare the exception or handle it

Many sorts of Exceptions

Name some exceptions you've seen raised in your programs ...

The `RuntimeException` Class

- Apart from `IOException`, the exceptions we've shown before are subclasses of the `RuntimeException` class
- Which itself is a subclass of the `Exception` class
- What's special about the `RuntimeException` class?

Programs do NOT need to catch such exceptions

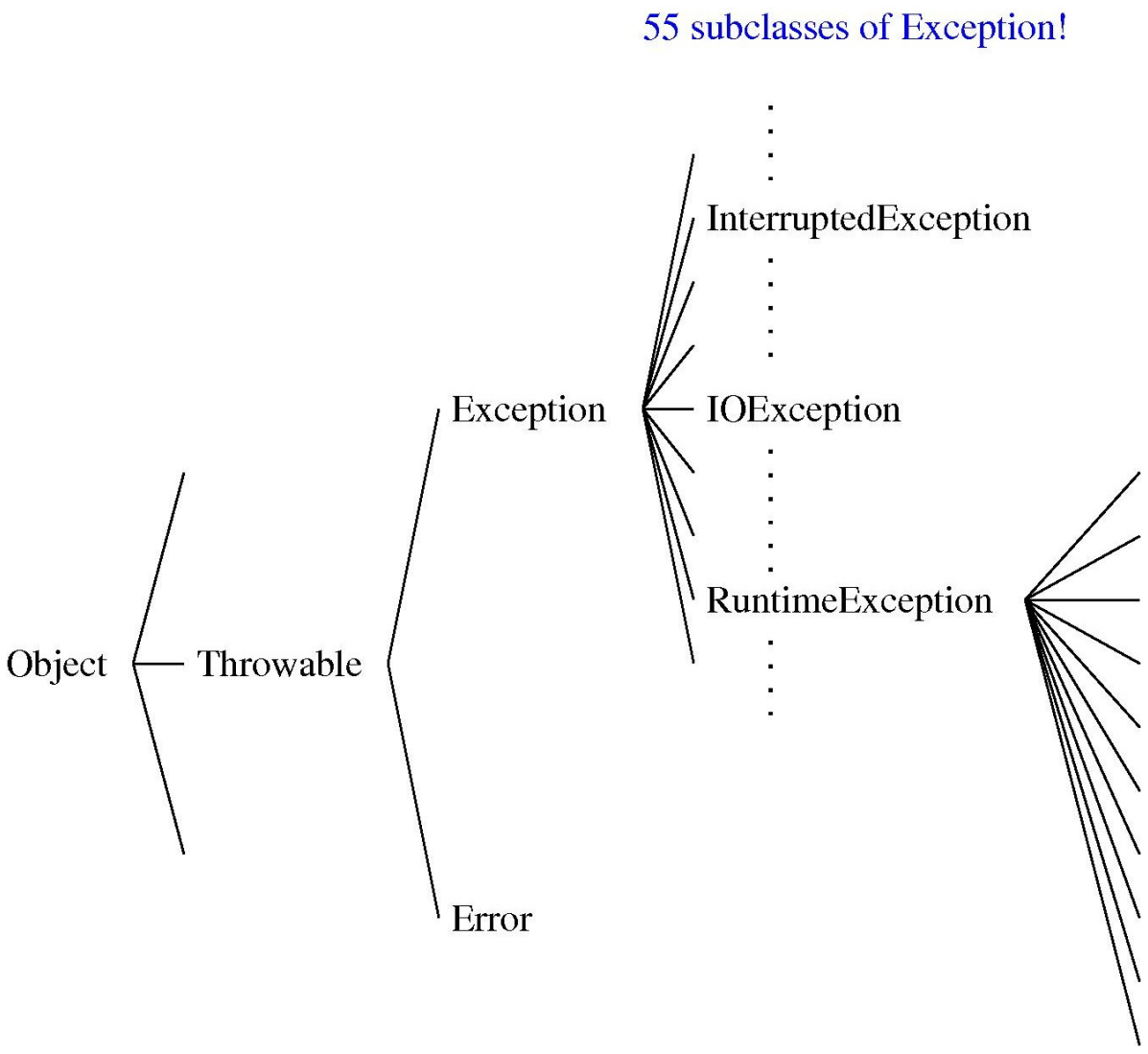
What about `IOException`? What happens there?

Throwable objects

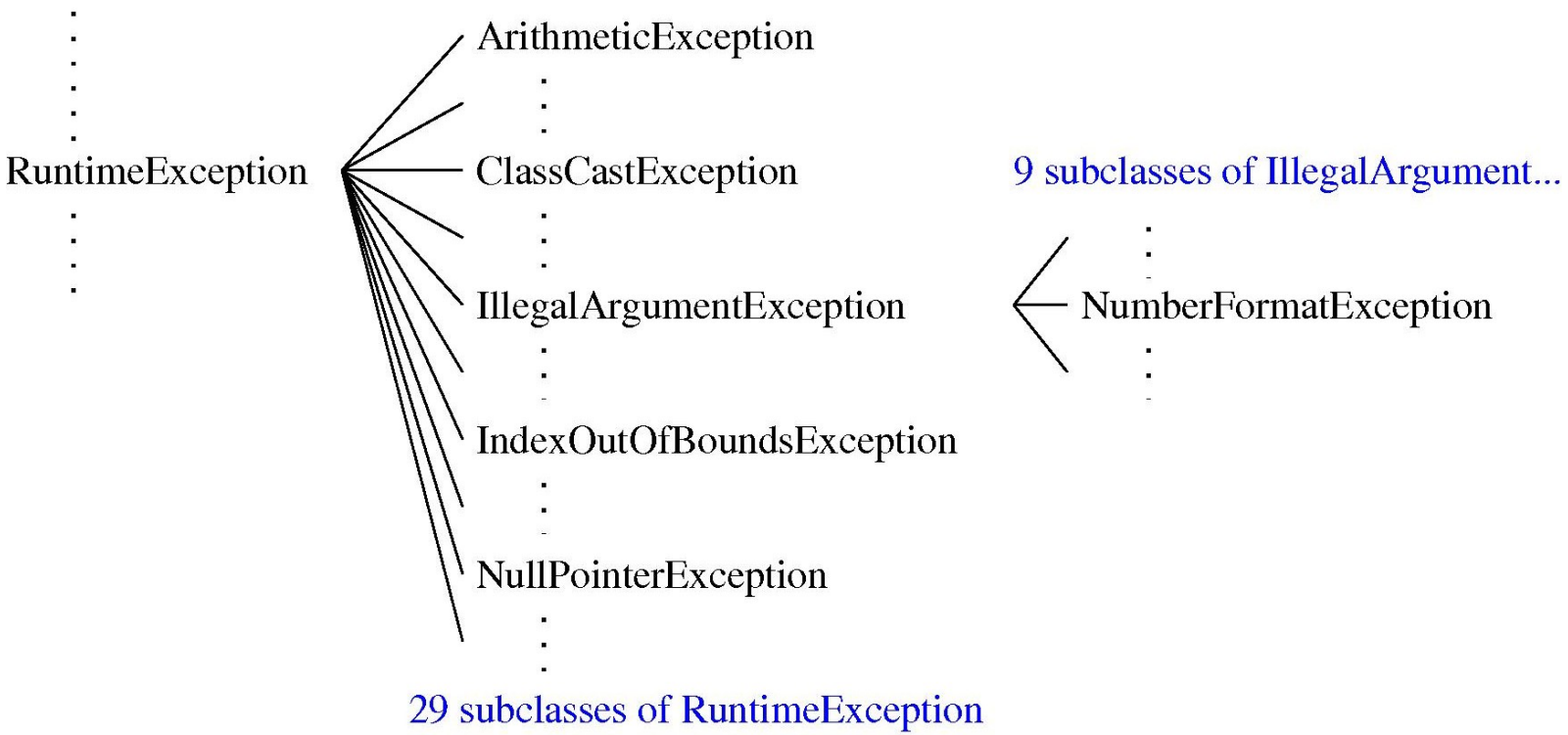
The Exception class is a subclass of the Throwable class, itself a subclass of Object

The Exception class has a very large number of subclasses.

Some of the Exception Class Hierarchy



More of the Exception Class Hierarchy



The `Error` class

The `Error` class is also a subclass of the `Throwable` class.

Errors can also be caught via a `try ... catch ...` block.

What's the difference between an `Error` and an `Exception`?

- Errors, e.g. `NoSuchMethodError` or `OutOfMemoryError`, are typically beyond rectification by the program
- Hence, instances of the `Error` class do not need to be caught — rather like `RuntimeException`
- However, if an `Error` is caught, it should be re-thrown and allowed to propagate out

Defining your own Exceptions

- Java API defines a very large number of exceptions
- BUT the programmer can still define her own
- How and when?
  - typically, for explicit throws of exceptions that don't appropriately relate to any of the API defined exception classes

The `Date` class revisited

Recall the re-usable `Date` class (chapter 14.7)

The constructor was modified to throw an exception for illegal dates

The exception object was an instance of class `Exception`

Better practice to create a special `DateException` and then throw an object of that class.

Question: Should we force the exception to be handled?

I.e., should `DateException` be a subclass of:

`Exception` or of `RuntimeException`?

The DateException class

```
public class DateException extends RuntimeException {

  public DateException() {
    super();
  }

  public DateException(String message) {
    super(message);
  }

}
```

Note: we have not overridden the superclass methods, `getMessage()`, etc.

Other required changes

The `Date` class is then modified by replacing

all occurrences of `Exception`

by `DateException`

Well, that's not quite right. There's one occurrence that should become a `RuntimeException`. Can you find it?

The DateDifference Program

```
public class DateDifference {
  public static void main(String [] args) {
    Date date1, date2;
    try {
      date1 = new Date(args[0]);
      date2 = new Date(args[1]);
      System.out.println("From " + date1 + " to " + date2
                         + " is " + date1.daysFrom(date2) + " days");
    } // try
    catch (ArrayIndexOutOfBoundsException exception)
      { System.out.println("Please supply two dates");
        System.err.println(exception); }
    catch (DateException exception)
      { System.out.println(exception.getMessage());
        System.err.println(exception); }
  } // main } // class DateDifference
```

And the difference is ...

Now we obtain:

```
$ java DateDifference 16/12/2004 30/2/2004
Day 30 must be from 1 to 29 for 2/2004
DateException: Day 30 must be from 1 to 29 for 2/2004
$ _
```

instead of previously

```
$ java DateDifference 16/12/2004 30/2/2004
Day 30 must be from 1 to 29 for 2/2004
java.lang.Exception: Day 30 must be from 1 to 29 for 2/2004
$ _
```

An Exceptional Notional Lottery

Chapter 16 presented the Notional Lottery case study.

It's prime purpose has been to demonstrate inheritance.

We can revisit a part, to add exceptions,
and define exceptions as subclasses of other user-defined exceptions.

We will focus on the abstract class `BallContainer`
and one its subclasses, the `Machine` class.

About the size of a `BallContainer`

The constructor for a `BallContainer` is passed the required maximum size.

What about a minimum size?

Sensible to ensure the container can hold at least one ball.

What should we do if the required maximum size is less than one?

Throw an exception! - A `BallContainerException`

The BallContainer constructor

```
public BallContainer(String requiredName,
                     int requiredMaximumSize)
          throws BallContainerException
{

  if (requiredMaximumSize < 1)
    throw new BallContainerException
                     ("Size must be at least 1");
  name = requiredName;
  balls = new Ball[requiredMaximumSize];
  noOfBalls = 0;

}
```

The BallContainerException class

```
public class BallContainerException extends RuntimeException
{
  public BallContainerException()
  {
    super();
  }

  public BallContainerException(String message)
  {
    super(message);
  }
}
```

Modification to other methods in the `BallContainer` class

The methods

- `getBall` — there may be no balls in the container
- `addBall` — there may be no room in the container
- `removeBall` — there may be no ball to remove
- `swapBalls` — the specified balls may not exist

all require attention.

The original SwapBall method

```
public void swapBalls(int i, int j) throws BallContainerException
{
  if (i >= 0 && i < noOfBalls && j >= 0 && j < noOfBalls)
  {
    Ball oldBallAtI = balls[i];
    balls[i] = balls[j];
    balls[j] = oldBallAtI;
  }
}
```

The new SwapBall method

```
public void swapBalls(int i, int j) throws BallContainerException
{
  if (noOfBalls == 0)
    throw new BallContainerException("Cannot swap balls: is empty");

  if (i < 0 || i >= noOfBalls)
    throw new BallContainerException("Swap ball at " + i
                  + ": not in range 0.." + (noOfBalls - 1));

  if (j < 0 || j >= noOfBalls)
    throw new BallContainerException("Swap ball at " + j
                  + ": not in range 0.." + (noOfBalls - 1));

  Ball oldBallAtI = balls[i];
  balls[i] = balls[j];
  balls[j] = oldBallAtI;
}
```

And now for the Machine

Again, is there a minimum size for a machine.

Sensible for it to hold at least two balls.

The Machine constructor

```
public Machine(String requiredName,
               int requiredMaximumSize)
        throws BallContainerException
{

  super(requiredName, requiredMaximumSize);

  if (requiredMaximumSize < 2)
    throw new MachineException("Size must be at least 2");

}
```

The MachineException class

MachineException should be a subclass of BallContainerException

```
public class MachineException extends BallContainerException
{
  public MachineException()
  {
    super();
  }

  public MachineException(String message)
  {
    super(message);
  }
}
```

The ejectBall method of the Machine class

```
public Ball ejectBall() throws MachineException
{
  try
  {
    int ejectedBallIndex = (int) (Math.random() * getNoOfBalls());

    Ball ejectedBall = getBall(ejectedBallIndex);

    swapBalls(ejectedBallIndex, getNoOfBalls() - 1);
    removeBall();

    return ejectedBall;
  }
  catch (BallContainerException exception){
    throw new MachineException("Cannot eject ball: is empty");
  }
}
```

Testing - I

```
public class TestMachineExceptions
{
  public static void main(String [] args)
  {
    int machineSize = Integer.parseInt(args[0]);
    int fillCount = Integer.parseInt(args[1]);
    int findIndex = Integer.parseInt(args[2]);
    int removeCount1 = Integer.parseInt(args[3]);
    int swapIndex1 = Integer.parseInt(args[4]);
    int swapIndex2 = Integer.parseInt(args[5]);
    int removeCount2 = Integer.parseInt(args[6]);
    int ejectCount = Integer.parseInt(args[7]);
```

Testing - II

```
try {
  System.out.println("Creating machine sized " + machineSize);
  Machine machine = new Machine("Test4U", machineSize);

  System.out.println("Filling with " + fillCount + " balls");
  for (int i = 1; i <= fillCount; i++)
    machine.addBall(new Ball(i, Color.red));

  System.out.println("Finding ball at " + findIndex);
  machine.getBall(findIndex);

  System.out.println("Adding another ball");
  machine.addBall(new Ball(fillCount + 1, Color.red));

  System.out.println("Removing " + removeCount1 + " balls");
  for (int i = 1; i <= removeCount1; i++)
    machine.removeBall();
```

Testing - III

```
      System.out.println("Swapping balls at " + swapIndex1
                         + " and " + swapIndex2);
      machine.swapBalls(swapIndex1, swapIndex2);

      System.out.println("Removing " + removeCount2 + " balls");
      for (int i = 1; i <= removeCount2; i++)
        machine.removeBall();

      System.out.println("Ejecting " + ejectCount + " balls");
      for (int i = 1; i <= ejectCount; i++)
        machine.ejectBall();
    } // try
    catch (Exception exception) {
      System.out.println("Got exception " + exception);
    } // catch
  } // main
} // class TestMachineExceptions
```

Testing - Some Results

OK, let's try it out ....

machine Size	fill Count	find Index	remove Count1	swap Index1	swap Index2	remove Count2	eject Count	expected result
0	-1	-1	-1	-1	-1	-1	-1	Size at least 1
5	5	5	-1	-1	-1	-1	-1	Get Ball at 5: not in range 0..4
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Summary

- Quick review of exception handling
- Large inheritance structure underneath the `Throwable` class
- Can create custom exception classes
- Rule of thumb:
  1. try to find suitable an existing exception classes
  2. none appropriate, create your own
  3. use inheritance as appropriate
  4. provide two constructors, without and with a message