Lecture Set #7:
Exceptions & Mutability Issues

1. Break and Continue for Loops
2. Exceptions
3. Mutability/Immutability
4. Stringbuffer class

break from loops
- break can also be used to exit immediately from any loop
  - while
  - do-while
  - for
- e.g. “Read numbers from input until negative number encountered”
  ```java
  Scanner sc = new Scanner(System.in);
  int n;
  while (true) {
    n = sc.nextInt();
    if (n < 0)
      break;
    else
      // process n;
  }
  ```
- Loop only terminates when break executed
- This only happens when \( n < 0 \)

Warning about break
- Undisciplined use of break can make loops impossible to understand
  - Termination of loops without break can be understood purely by looking while, for parts
  - When break included, arbitrary termination behavior can be introduced
- Rule of thumb: use break only when loop condition is always true (i.e. break is only way to terminate loop)
- When you use it, make sure it has a good comment explaining what is happening
**Continue Statement**

- `continue` can also be used to affect loops
- `break` halts loops
- `continue` jumps to bottom of loop body
- Following prints even numbers between 0 and 10
  ```java
  for (int i = 0; i <= 10; i++)
  
  if (i % 2 == 1)
  
  continue;
  
  System.out.println(i);
  
  }
  
  Effect of `continue` statement is to jump to bottom of loop immediately when `i` is odd
  - This bypasses `println`!
  - `continue` should be avoided
  - Confusing
  - Easy equivalents exist (e.g., `if-else`)
  - Included in Java mainly for historical reasons
  - When you use it, make sure it has a good comment explaining what is happening

**Exceptions**

- Programs can generate errors
  - Arithmetic: Divide by zero, overflows, ...
  - Object / Array: Using a null reference, illegal array index, ...
  - File and I/O: Nonexistent file, attempt to read past the end of the file, (we’ll see more about file I/O later in course), ...
  - Application-specific: Errors particular to application (e.g., attempt to remove a nonexistent customer from a database)
- In Java: something that is outside the norm = `exception`
- What to do when an error occurs?
  1. Basic ignore it: Print an error message and terminate?
  2. Have the method handle it internally: Handle error in the code where the problem lies as best you can.
  3. Have the method pass it off to someone else to handle: Return “error code” so that whoever called this function can handle it.
  4. Modern language approach: Cause “exception” to be thrown (and caught (or processed) by any function up the stack trace)

**Exception Behavior**

- If program generates (“throws”) exception then default behavior is:
  - Java clobbers (“aborts”) the program
  - Stack trace is printed showing where exception was generated (red and blue in Eclipse window)
- Example
  ```java
  public static int mpg(int miles, int gallons){
  
  return miles/gallons;
  
  }
  
  ```
  - Throws an exception and terminates the program.
Throwing Exceptions Yourself

- To throw an exception, use throw command:
  ```java
to e;
e must evaluate to an exception object
```
- You can create exceptions just like other objects, e.g.:
  ```java
Runtime Exception e = new RuntimeException("Uh oh");
```
- `RuntimeException` is a class
- Calling new this way invokes constructor for this class
- `RuntimeException` generalizes other kinds of exceptions (e.g. `ArithmeticException`)

Exceptions, Classes and Types

- Exceptions are objects
- Some examples from the Java class library (mostly java.lang):
  - `ArithmeticException`: Used e.g. for divide by zero
  - `NullPointerException`: Attempt to access an object with a null reference
  - `IndexOutOfBoundsException`: Array or string index out of range
  - `ArrayStoreException`: Attempt to store wrong type of object in array
  - `EmptyStackException`: Attempt to pop an empty Stack (java.util)
  - `IOException`: Attempt to perform an illegal input/output operation (java.io)
  - `NumberFormatException`: Attempt to convert an invalid string into a number (e.g., when calling `Integer.parseInt()`)
  - `RuntimeException`: General run-time error (subsumes above)
  - `Exception`: The most generic type of exception

Java Exceptions in Detail

- Exceptions are (special) objects in Java
  - They are created from classes
  - The classes are derived ("inherit") from a special class, `Throwable`
  - We will learn more about inheritance, etc., later
- Every exception object / class has:
  - `Exception(String message)`
    Constructor taking an explanation as an argument
  - `String getMessage()`
    Method returning the embedded message of the exception
  - `void printStackTrace()`
    Method printing the call stack when the exception was thrown
Handling Exceptions

- Aborting program not always a good idea
  - E-mail: can’t lose messages
  - E-commerce: must ensure correct handling of private info in case of crash
  - Antilock braking, air-traffic control: must recover and keep working
- Java includes provides the programmer with mechanisms for recovering from exceptions

Java Exception Terminology

- When an anomaly is detected during program execution, the JVM throws a particular type of exception
  - There are built-in exceptions
  - Users can also define their own (more later)
- To avoid crashing, a program can catch a thrown exception (if it isn’t caught – you see the red and blue messages – stack trace)
- An exception generated by a piece of code can only be caught if the program is alerted. This process is called trying the piece of code.

Exception Propagation

- In previous example:
  - Exception thrown in one method …
  - … but caught in another
  - Java uses exception propagation to look for exception handlers
  - When an exception occurs, Java pops back up the call stack to each of the calling methods to see whether the exception is being handled (by a try-catch block). This is exception propagation
  - The first method it finds that catches the exception will have its catch block executed. Execution resumes normally in the method after this catch block.
  - If we get all the way back to main and no method catches this exception, Java catches it and aborts your program
Exception Handling: Example

- **DateReader.java**
  - Prompts user for a date in mm/dd/yyyy format
  - Prints year
  - **Program uses:**
    - `substring` method
      - May throw `IndexOutOfBoundsException`
    - `Integer.parseInt` method
      - May throw `NumberFormatException`
    - `getYear` method (if `d` is null)
      - May throw `NullPointerException`
  - How do we know about these exceptions? Javadoc!
    - [http://java.sun.com/j2se/1.5.0/docs/api/java/lang/package-summary.html](http://java.sun.com/j2se/1.5.0/docs/api/java/lang/package-summary.html)

What about Strings and Aliasing?

- **String** objects are *immutable*; fields cannot be changed once created
  - *Mutable* objects: fields (values of instance variables) can be changed (e.g. Cat, Student, etc.)
  - *Immutable* objects: fields (values of instance variables) cannot be changed
  - See [String API](http://java.sun.com/j2se/1.3/docs/api/java/lang/package-summary.html)

- In the Cat and CatOwner example:
  - when one object is assigned to another, an alias is created
    - `Cat a = new Cat("Fluffy");`
    - `Cat b = a;`

Which picture represents the current status of memory?

- [Memory diagram](http://java.sun.com/j2se/1.5.0/docs/api/java/lang/package-summary.html)
Mutable Strings

- Strings are immutable
  - Once a String object is created, it cannot be altered
- Sometimes mutable strings would be handy
  - Sometimes a small change needs to be made to a string (e.g., misspelled name)
  - Don’t want to create a whole new String object in this case
- StringBuffer: Java’s class for mutable Strings

StringBuffer Basics

- See documentation at: http://java.sun.com/j2se/1.5.0/docs/api/java/lang/StringBuffer.html
- Main methods
  - append: add characters to end
  - insert: add characters in middle
  - delete: remove characters
- Note
  - append, insert return object of type StringBuffer
  - This is alias to object that the methods belong to!
- See StringBufferExample.java