CSC 143 Java

Errors and Exceptions

What Can Go Wrong With Programs?

- Programs can have bugs and try to do things they shouldn't.
  - E.g. try to send a message to null
- Users can ask for things that they shouldn't (we can't control the user).
  - E.g. try to withdraw too much money from a bank account
- The environment may not be able to provide some resource that is needed
  - Program runs out of memory or disk space
  - Expected file is not found
  - Extreme network examples:
    - Thousands to millions of tiny sensors (one or more sensors break down)
    - Interplanetary Internet (a server is down)

Coping Strategies

- Check all user input! (Not doing this has led to many insecurities.)
  - But what should the program do if it's wrong?
- Be able to test whether resources were unavailable.
  - But what should the program do if they weren't?
- Other strategies?

Reporting Errors with Status Codes

- If a method cannot complete properly because of some problem, how can it report it to the rest of the program?
- One approach: return a **status code** (**error code)**
- Boolean status flags are very common
  - A boolean flag: true means OK, false means failure
- Integers or other types could be used
  - An integer flag: 0 means OK, 1 means error of kind #1, etc.
  - For object return types: null could mean error, non-null could mean success
- What's bad about using this idea of returning a status code?

Status Codes in BankAccount

- In a BankAccount class that processes banking transactions:

```
public boolean deposit   (double amount) { return this.updateBalance(amount); }
public boolean withdraw(double amount) { return this.updateBalance(-amount); }

private boolean updateBalance(double amount) {
  if (this.balance + amount < 0) {
    System.out.println("Sorry, you don't have that much money to withdraw.");
    return false;
  } else {
    this.balance = this.balance + amount;
    return true;
  }
}
```

- What do you think?

Status Codes: Pro and Con

- Easy to program, in the method that detects the error

```
MyObject methodThatMightFail(…) {
   … if (weirdErrorCondition()) { return null;
      } else {
      //continue and create an object to return
   …
     }
}
```

- Can be bothersome for callers (why?)
- Can be unreliable (why?)

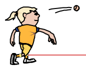
An Alternative: Throwing Exceptions

- Java (and C++, and many modern languages) include **exceptions** as a more sophisticated way to report and handle errors
- If something bad happens, program can **throw** an exception
  - A throw statement terminates the throwing method
  - throw sends back a value, the exception itself.
- So far it sounds a lot like the return statement
  - A return statement terminates the method
  - return can send a value back to the caller

Revised BankAccount Methods

```
public void deposit   (double amount) { this.updateBalance(amount); }
public void withdraw(double amount) { this.updateBalance(-amount); }
private void updateBalance(double amount) {
  if (this.balance + amount < 0) {
    throw new IllegalArgumentException("insufficient funds");
  } else {
    this.balance = this.balance + amount;
  }
}
```

- Methods now have void return type, not boolean
- Error message and "return false" replaced with throw of new exception object
- Callers can chose to ignore the exception, if they don't know how to cope with it
  - It will be passed on to the caller's caller, and so on, to some caller that can cope



Return vs Throw

- A return takes the execution right back to where the method was called
  - Sometimes referred to as the "call site"
- A throw takes the execution to code (the **handler)** designated specifically to deal with the exception
  - The handler is said to **catch** the exception
- The handler might not be at or near the call site
- The calling (client) module might not even have a handler
- If a handler doesn't exist somewhere, the program aborts

Throw Statement Syntax

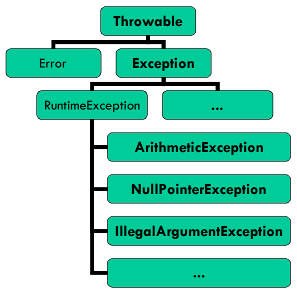
- To throw an exception object, use a throw statement
  - Syntax pattern:

    throw *<expression>* **;**
- The expression must be an object of type throwable
  - There are many such classes already defined
  - BankAccount example used IllegalArgumentException
  - The expression can't be omitted
- But it doesn't just return to the caller, but ends execution of the caller, and its caller, and so on, until a handler is found (explained later), or the whole program is terminated
  - It's bad practice for a complete program to die with an unhandled exception

Exception Objects In Java

- Exceptions are regular objects in Java
- Exception are subclasses of the predefined Throwable class
- Some predefined Java exception classes:
  - RuntimeException (a very generic kind of exception)
  - NullPointerException
  - IndexOutOfBoundsException
  - ArithmeticException (e.g. for divide by zero)
  - IllegalArgumentException (for any other kind of bad argument)
- Most exceptions have constructors that take a String argument

Throwable/Exception Hierarchy



What about Handlers?

- As we said, return and throw have some similarities
- When a method ends as a result of a throw...
  - If the caller has a handler, that's where execution continues
  - If the caller doesn't have a handler, then its caller is checked to see if there is a handler.
  - This checking of callers proceeds up the line, until a handler is found; if there isn't one anywhere, the program aborts.
- That's the big picture. A few details later.

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Specifying an Exception Handler

- If a caller knows how to cope with an exception, then it can specify an appropriate handler using a **try-catch block**

```
try {
    mySavingsAccount.withdraw(100.00);
    myCheckingAccount.deposit(100.00);
} catch (IllegalArgumentException exn) {
    System.out.println("Transaction failed: " + exn.getMessage());
}
```

- The **catch** part of the block constitutes the handler.
- If an exception is thrown anywhere inside the body of the try block, that is an instance of IllegalArgumentException or a subclass, then the exception is caught and the catch block is run

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Try-Catch Blocks: Syntax

- Syntax:

```
try {
    <body, a sequence of statements>
}
catch (<exception type1> <name1>) {
    <handler1, a sequence of statements>
}
catch (<exception type2> <name2>) {
    <handler2, a sequence of statements>
}
…
```

  - Can have one or more catch clauses for a single try block

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Try-Catch Blocks: Semantics

- First evaluate <*body*>
- If no exception thrown during evaluation of *body*, or all exceptions that are thrown are already handled somewhere inside *body*, then we're done with the try-catch block; skip the catch blocks
- Otherwise, if an exception is thrown and not handled, then check each catch block in turn
  - See if the exception is an instance of <*exception type1*>
  - If so, then the exception is caught:
    Bind <*name1*> to the exception; execute <*handler1*>; skip remaining catch blocks and go to the code after the try-catch block
  - If not, then continue checking with the next catch block (if any)
- If no catch block handles the exception, then continue searching for a handler, e.g. by exiting the containing method and searching the caller for a try-catch block surrounding the call

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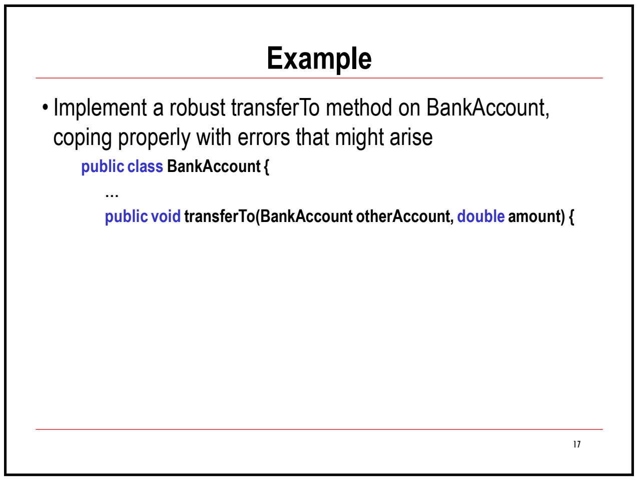

Example

- Implement a robust transferTo method on BankAccount, coping properly with errors that might arise

```
public class BankAccount {
    …
    public void transferTo(BankAccount otherAccount, double amount) {
```

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