COMP90041
Programming and Software Development

Exceptions

Semester 2, 2015

If anything can go wrong...

- Error handling is difficult because the code that knows what to do when a problem happens is different from the code that detects the problem
- Two traditional ways to handle errors:
  1. return a result indicating whether operation succeeded
  2. Print an error message and exit
- Approach **??** is terrible;
  - **Very** common for programmers to fail to check return code, and just assume everything is OK
  - A method can only return one result, if it already needs to return one, how to also return the success code?
- Approach **??** is worse:
  - No way to recover from the program exiting!
  - This means every call to a method that could experience a problem must first test if there will be a problem

Exceptions

- Exceptions give the best of both worlds:
- Write code mostly without worrying about what to do if something goes wrong
- In places where you know what to do if something goes wrong, you can still catch it and handle it
- If you don't handle an exception at all, it aborts the program
- Two sides to exception handling:
  - Throwing
  - Catching

Exceptions

- An exception is an object indicating what went wrong
- The class of the exception object indicates broadly what's wrong
- Extra information in the form of a message string gives details
- Some methods of all exception classes:
  - `toString()` returns a string describing the exception
  - `getMessage()` returns a string with detail about the error, or `null`
  - `printStackTrace()` print a backtrace of what was happening when the exception happened (only useful to programmers)

Throwing

- Throwing an exception signals an error has occurred
- Currently executing code is interrupted and abandoned
- If exception is not caught in the current method, it will flow up to the calling method
- If caller doesn't catch it, it percolates up until it is caught
- If it's never caught, the program is aborted, printing a backtrace
- Use exceptions only for exceptional circumstances, not as a quick way to jump around your code

throw

- Form: `throw` *`exceptionObject`*
- Typically create the exception at the same time:
  `throw new` *`exceptionClass(detailString);`*
- Or: `throw new` *`exceptionClass();`*
- For example:

```
public Person(int age, String name) {
    if (name == null) {
        throw new NullPointerException(
            "Creating person with null name");
    }
    this.age = age;
    this.name = name;
}
```

Handling Exceptions

- Handling an exception means providing code to execute to recover from code going wrong
- Form:

```
try {
    code that may go wrong...
} catch (ExceptionClass var) {
    code to handle exception...
}
```

- `try` part specifies code that may throw an exception
- `catch` parameter specifies the kind of exception to catch
- Code inside the `catch` clause specifies what to do if that exception occurs

Executing `try...catch`

- Use `try...catch` like an ordinary statement

```
try {
    code that may go wrong...
} catch (ExceptionClass var) {
    code to handle exception...
}
```

- First execute *code that may go wrong...*
- If it completes without exception, ignore (skip over) *code to handle exception*
- If it throws an exception matching *ExceptionClass*, bind *var* to exception object and execute *code to handle exception*
- Either way, then go on to following statements

Catching

- `catch` parameter has two roles:
  - To specify the kind of exception to catch
  - To name a variable to hold the exception object (`e` is often used as variable name)
- `catch` parameter is scoped to (only defined in) that exception handler
- Can have multiple `catch`es in immediate succession
  - Only one handler is executed, others are ignored
  - First one that matches the thrown exception is used
- If no `catch` clause exception class matches thrown exception, it is not caught by that `try...catch`
  - Propagates to caller as if code were not in a `try...catch`

Pitfall: Order of catches

- Always put more specific (descendant class) catches before more general (ancestor class) ones
- More general one will always match when the more specific one would, so more specific one will never be used

```
try {
    ...
} catch (Exception e) {
    // This code will be used for any
    // descendent of Exception class
} catch (NumberFormatException e) {
    // This will never be used: NumberFormatException
    // is a descendent of Exception
}
```

Inside a `catch` block

- `catch` block should try to recover from error
- Can use exception object (commonly parameter `e`)
- `e.getMessage()` returns exception message
- Can use known class of exception to decide action
- If `catch` block cannot resolve the problem, it can always throw the same exception (just `throw e;`)
- Or `catch` block can throw a different exception
- Exception thrown inside `catch` block will not be caught by that `try...catch`
  - Only exceptions thrown inside the `try` block are caught by that `try...catch`

The `finally` Block

- A `finally` block allows you to perform clean ups regardless of whether or not an exception is thrown
- `finally` block is attached to a `try...catch` following all the `catch`es
- Form:

```
try {
    ...
} catch (...) {
    ⋮
} finally {
    code to execute regardless
}
```

- Use this with `try` block, with or without `catch`es

When `finally` Block is Executed

- `finally` block is executed almost no matter what
- If `try` block completes without error, `catch`es are skipped and `finally` block is executed
- If inside `try` an exception with matching `catch` is thrown, `catch` is executed, then `finally` block
- If no matching `catch`, `finally` block executes, then exception propagates to caller
- If matching `catch` block throws exception, `finally` block executes, then exception propagates to caller
- Only if `try` or `catch` is infinite loop, or calls `System.exit`, will `finally` block be missed
  - So don't do that!

Kinds of Exceptions

- Java distinguishes a few different kinds of exceptions:
- Everything that can be `thrown` is a descendent of the `Throwable` class
- Subclasses of `Throwable`:
  - `Error`: a serious error that could occur at any time, such as JVM failure
  - `Exception`: exceptional circumstance in executing your code
- Subclasses of `Exception`:
  - `RuntimeException`: an exception that could happen at any time in normal Java code (*e.g.* null pointer)
  - . . . and many, many more specific exception classes

Kinds of Exceptions

- You should not try to catch descendents of `Error`; there is not much you can do about such failures
- Descendents of `RuntimeException` indicate an error that your code has failed to prevent
- Rather than catch `RuntimeException`s, you should fix your code to avoid them, *e.g.*:
  - `NullPointerException`: check that variables are not null before sending them a message
  - `ArrayIndexOutOfBoundsException`: ensure that index is within bounds before accessing array element
  - *Etc.*
- (But it's fine to throw `RuntimeException`s)
- Other descendents of `Exception` should be caught and handled where you know how to handle them

Checked and Unchecked Exceptions

- Descendents of `Error` and `RuntimeException` are called unchecked exceptions
- Other descendents of `Exception` are called checked exceptions
- Each method must declare any checked exceptions that may be propagated out
- "Catch or declare" rule: each method must declare that it may throw:
  - Any checked exceptions that may be thrown by the method, and
  - Any checked exceptions declared to be thrown by methods it calls
  - Except those that are caught and handled by the method body

`throws` clause

- Declare what checked exceptions a method can throw with a `throws clause`
- Form: `throws` *`ExceptionClass`*
- Place this after method signature in concrete or abstract method declaration
- Declare multiple throws by listing all of them separated by commas
- *E.g.*,

```
public LostPerson readLostPersonFile(String fileName)
    throws FileNotFoundException, EOFException { ... }
```

`throws` clause

- A method may not expand overridden method's `throws` clause (but may reduce it)
- Method may throw any descendent of exceptions listed in `throws` clause
- So `throws` clause can generalise multiple exception classes to a common ancestor
- *E.g.*, `IOException` is the base class of both `FileNotFoundException` and `EOFException`, so:

```
public LostPerson readLostPersonFile(String fileName)
    throws IOException { ... }
```

- But this obliges callers to catch or declare all kinds of `IOException`s

Defining Exceptions

- Can define your own exception classes
- Must be descendent of `Exception` class
- Pick the right place in the exception taxonomy
  - *E.g.*, if it's an I/O related error, make it a descendent of `IOException`
- Make sure `getMessage` works right
- Usually you should define constructors with no argument and a single String argument
- Many user exception classes just have constructors:

```
public MyException(String msg) { super(msg); }
public MyException() {
    super("default description string");
}
```

Introduction to Software Engineering

- *Cheops Law: Nothing ever gets built on schedule or within budget.* — Robert Heinlein
- Goes doubly for software projects
- Statistics vary depending on how you define success/failure, but roughly:
  - 1 in 6 projects fail outright
  - 1 in 2 projects complete over budget
  - 1 in 3 projects succeed
- Costs 10s of $Billions every year
- Reasons for failure include:
  - Unrealistic or unarticulated goals
  - Inaccurate estimation of needed resources
  - Badly defined system requirements
  - Poor project management
  - Inability to handle complexity

Victorian Example

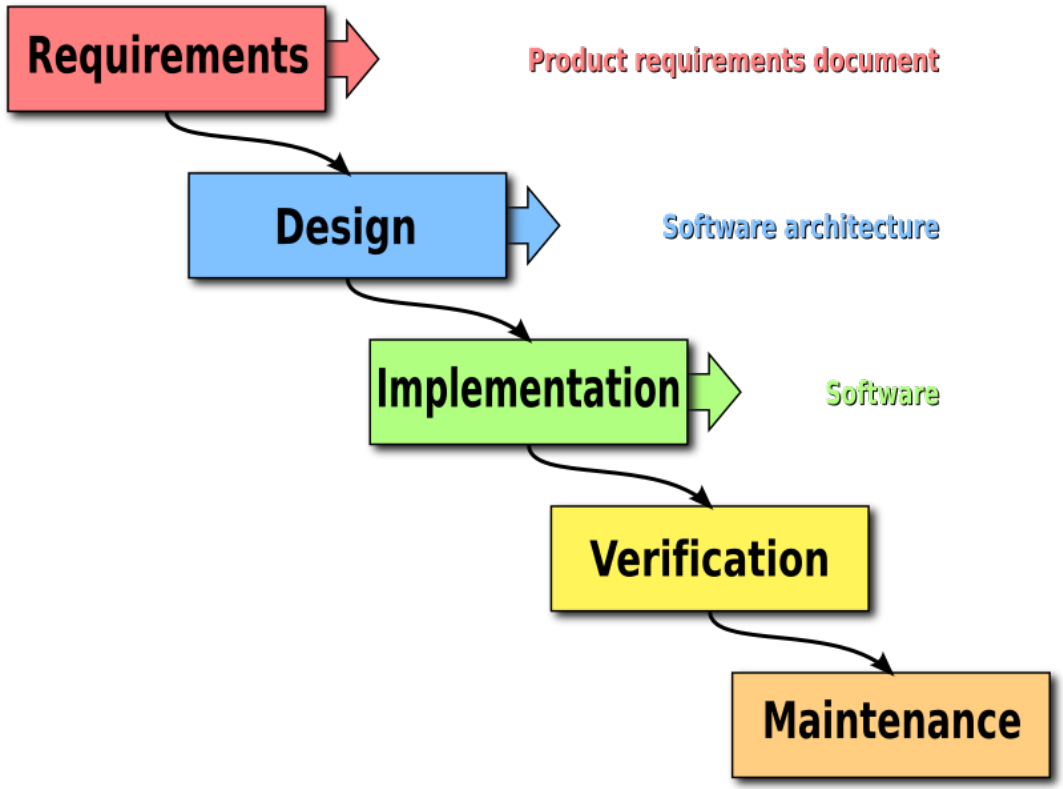
- Project started in 2005 to replace the aging LEAP police database Budgeted $50 Million
- In 2009, budget blew out to $130M
- In 2011, new business case saw budget blow out to almost $200M
- Project halted because it didnt handle changing policing requirements
- They're still using LEAP

Software Engineering

- Software Engineering evolved beginning in the 1960s to solve the "Software Crisis"
- Software development practices and processes are still evolving
- Basic idea: consider phases of software development (software development life cycle):
  - **Requirements specification**: determine what system must do
  - **Design**: determine how to make the system do what it must
  - **Implementation**: code the system
  - **Validation**: make sure the system actually does what it must do
  - **Maintenance**: keep the system doing what it must do as needs change or problems are discovered

Waterfall Model

- Classic life cycle model is the waterfall model
- Phases of development are followed in order



- Phases can backtrack to earlier phase if (when) necessary

Agile Software Development

- The waterfall model often breaks down because:
  - Client rarely know what they need or want
  - Clients and developers rarely communicate visions well
  - Needs change as software is developed
  - Clients get impatient
- Agile development is more popular now
- Agile software development is an incremental software development methodology
- Continuous delivery — delivery every 1–4 weeks
- Focus on communication — daily short meetings
- Focus on client satisfaction and adaptation to changing client needs

Summary

- `throw new ExceptionClass(...)` to signal error
- `try { ...}`
  `catch (ExceptionClass e) { ...}`
  to catch and handle exception
- Use `finally { ...}` to give cleanup code that will almost always be executed
- Must declare uncaught checked exceptions with `throws ExceptionClass` in method declaration
- Unchecked exceptions shouldn't be caught
  - Fix bugs that lead to `RuntimeException`s
- Software engineering focuses on best processes to develop working software on time and within budget