Programming Languages: Exception Handling

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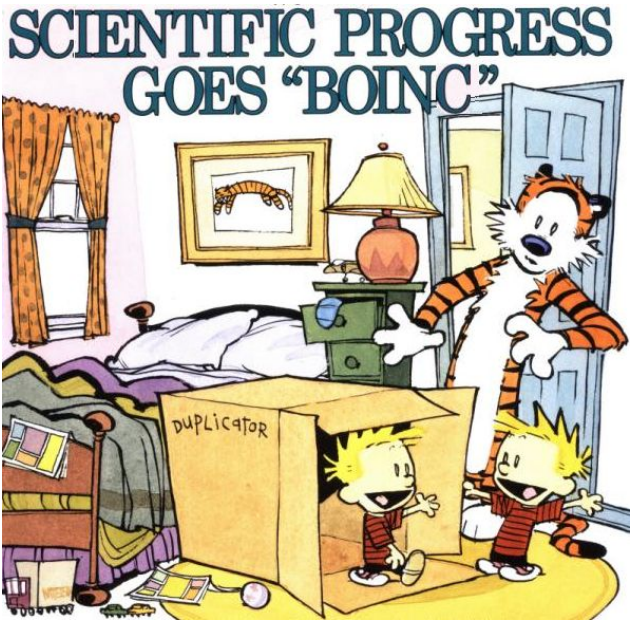

SCIENTIFIC PROGRESS
GOES "BOINC"
DUPLICATOR

Calvin and Hobbles

Overview: Exception Handling

- Goals
- Blocks not resumption
- Propagation
- Features in different languages
- “Final wishes”

- Sebesta 11th. Chapter 14: Exception Handling and Event Handling
- Louden & Lambert 3rd. Section 9.5: Exception Handling
- Scott 4th. Section 9.4: Exception Handling

What are exceptions?

Bad things happen occasionally at runtime.

arithmetic: $\div 0$, $\sqrt{-9}$

environmental: no space, malformed input

undetectable: subscript out of range, value does not meet prescribed constraint

others: can't invert a singular matrix, can't pop an element from an empty stack

Both hardware-detectable and software-detectable conditions. Which is which may depending on language implementation, hardware, etc.

Exceptions

Exceptions are said to be *raised* or *thrown* at the moment of detection, and are said to be *handled* or *caught* at the point when normal execution resumes.

Raising an exception halts normal execution abruptly and alternative statements are sought to be executed, possibly the program terminates.

Usually exceptions can be named; there are predefined exceptions and user-defined exceptions.

Exception Handling Goals

1. Separate normal flow of control from error handling
2. Incur no execution-time penalty

Return-Code

```
if ((fd=open(name, O_RDONLY))==-1) {
    fprintf (stderr, "Error %d opening file", errno);
    exit();
}
```

See also the C program from Stevens.

main.c

The Rust and Go programming languages do not have exceptions.

```
func Sqrt(f float64) (float64, error) {
    if f < 0 {
        return 0, errors.New("math: square root of negative r
    }
    // implementation
}

v, err := Sqrt(-1)
if err != nil {
   fmt.Println (err)
}
```

> *In Go, error handling is important. The language's design and conventions encourage you to explicitly check for errors where they occur (as distinct from the convention in other languages of throwing exceptions and sometimes catching them). In some cases this makes Go code verbose, but fortunately there are some techniques you can use to minimize repetitive error handling.*

Blog Post by Gerrard, 2011.

Exceptions

A programmer can program defensively in a programming language without support for exceptions. But there are many problems with ad hoc approach:

- Easy to ignore, hence error prone
- Poor modular decomposition
- Hard to test such programs
- Inconsistency — sometimes null, sometimes -1
- No additional info

Lang and Stewart, TOPLAS, 1998.

Exceptions

In general, an exception should be used when there is an inability to fulfill a specification.

Why not a precondition and an assert statement? Some cases are difficult to describe or detect; some cases are too rare concern the ordinary users of the code.

Indeed, assertions are often the same things as exceptions: a runtime signal of problem stopping the program from committing some unintended actions.

So, assertions for debugging and testing, preconditions for documentation and verification, exceptions are something else.

In Python an assertion raises the exception `AssertionError`.

```
import sys
assert ('linux' in sys.platform), "Linux only")
```

- Ada
- C++
- Modula-3
- Java, Kotlin
- Scale
- C#
- Python
- SML

See also `setjmp`/`longjmp` in C and `callcc` in functional languages.

No exception handling in Haskell as a matter of purity.

Exceptions in PL

- **Exception propagation**, resumption versus block-structured
- Named exceptions, user-defined and predefined exceptions
- Exceptions as values or separate entities
- Exceptions with arguments (additional information)
- Catch or declare
- Handling exceptions out of the scope of their names, one handler for all exceptions, re-raising exceptions in a handler
- Final wishes, return and exit as exceptions

Blocks With Handlers

In most languages a set of handlers watches over a block of code. When an exception is raised somewhere (perhaps in a subroutine call) in the block, execution stops at that point and a handler is sought. If one of the handlers is invoked after a successful search, the code of the handler is executed (naturally), and then the entire block ends as if no exception were ever raised.

```
TRY
    (* a section of executable statements *)
EXCEPT
    | One_Exception =>       (* one handler *)
    | Another_Exception => (* another handler *)
END
```

Blocks With Handlers

```
try:
    pass # a section of executable statements
except OneError:
    pass # one handler
except AnotherError:
    pass # another handler
```

(In Python, exceptions are traditionally named something ending in `Error`. In Java, for instance, an error is a runtime situation that you normally cannot handle.)

Try Blocks

```
try:
    pass # a section of executable statements
except:
    pass # any exception
else:
    pass # no exception
```

Resumption and Propagation

There is no attempt at going back and finishing the remaining actions in the block. PL/I tried implicit resumption after handling exceptions, but this is confusing. The programmer can still program any sort of resumption imaginable by careful use of blocks.

Exception propagation. Modern languages all take the same approach to *exception propagation*, the search for the place to resume normal execution: follow the dynamic chain of block activations. This is obviously correct: the caller who asked for the service should hear of the failure. On the other hand, declarations of exception names follow the same static scope rules as all identifiers.

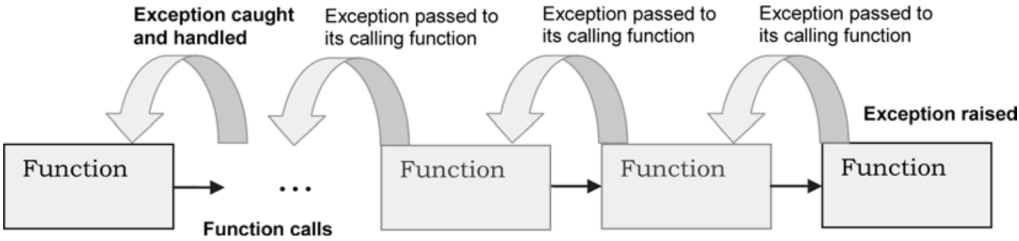


FIGURE 8-9 The Propagation of Exceptions

An exception is either handled by the client code, or automatically propagated back to the client's calling code, and so on, until handled. If an exception is thrown all the way back to the main module (and not handled), the program terminates displaying the details of the exception.

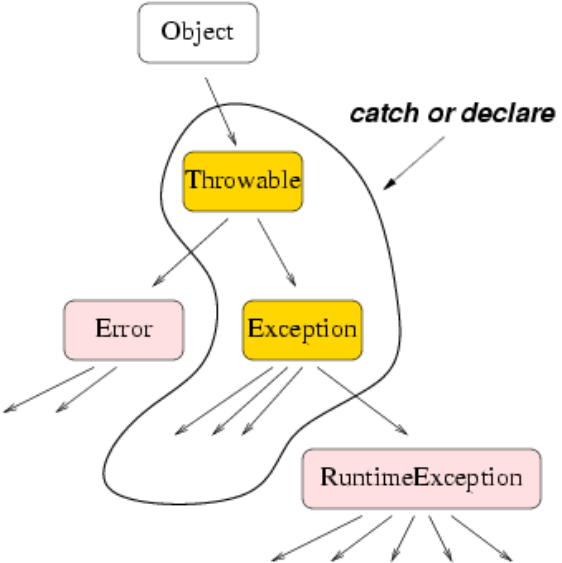
Dierbach, Introduction to CS, 2013, page 305

Examples

```
declare
   -- An exception is a signal of somesort, a new kind
   -- entity, separate for values to compute with.
   E: Exception; -- Declaration of exception 'E'
begin
   raise E with "message";
exception
    when E => null;   -- handler
end;
```

Examples

except/Pre.java – simple example with predefined exceptions
except/main.adb – simple example with predefined exceptions
except/calls.adb – recall runtime stack
except/calls2.adb – dynamic propagation
except/propagation.adb – much the same with print statements
except/propagation2.adb – `others`, multiple exceptions handler
except/Value.java – exceptions are classes in Java except/Declare.java
– catch or declare; exceptions important to specifications
except/Trace.java – stack trace is useful; don't "swallow" exceptions


Object
catch or declare
Throwable
Error
Exception
RuntimeException

Exceptions in Python

Exceptions in Python are similar to Java. Like Java they are classes.

```
try:
  # block of code
  pass
except NameError:
  pass
except KeyError:
  pass
```

Exceptions can be built-in exceptions (e.g., `IndexError`, `SyntaxError`, user-defined exceptions, or user-defined classes.

Exceptions in Python

Exceptions are like classes as in Java.

```
try
  pass
except KeyError as err:
    # Bind the exception instance to 'err'
except (AttributeError, TypeError, SyntaxError):
    # Multiple (and subclass, too!)
except:
    # wildcard; all other exceptions
    raise  # reraise the exception
else:
    # no exception raised
```

A `raise` statement without an exception name and in a handler reraises the current exception.

Exceptions in Python

Exceptions are like classes as in Java.

```
class B(Exception):
    pass

class C(B):
    pass

class D(C):
    pass

for cls in [B, C, D]:
  try:
     raise cls()
  except D:
     print("D")
  except C:
      print("C")   # Order matters
  except B:
```

Exception Occurrences

Just exactly what is an exception. What exactly is an exception occurrence? When is one generated? If two exceptions have the same name are they the same?

- `except/occur.adb` – exceptions are usually global signals
- `except/recurse.adb` – but they can be declared locally
- `except/Recurse.java` – local scope
- `except/Recurse2.java` – local scope

Exception Scope

Because exceptions propagate along the dynamic chain and their scope follows the static structure of the program, it is possible for an exception to propagate out of its scope.

- `except/out_of_scope.adb`
- `except/madness.adb` (uses packages)

Final Wishes

Even if a subprocedure cannot fix an exceptional case and must propagate the problem back up to its caller, it still may wish to undo the mess it is responsible for before relinquishing control for good. Exception handling seems like a good way to handle "final wishes."

- `except/final.adb` – `others` clause

Final Wishes

Modula-3:

```
TRY
   (* executable statements *)
FINALLY
   (* final wishes *)
END
```

Java has one combined statement:

```
try {
   // executable statments
} catch (Exception e) {
   // handler for ‘‘e’’
} finally {
   // 1. normal, 2. caught exc, 3. uncaught
   // exc, 4. break, continue, 5. return
   // final wishes
```

Java's `try` is Combination

Modula-3:

```
TRY
   TRY
      (* executable statements *)
   EXCEPT
      (* handlers *)
   END
FINALLY
   (* final wishes *)
END
```

Final Wishes in Python

It is combined in Python

```
try:
  pass # executable statements
except:
  pass # handler for any exception
finally:
  pass # final wishes
```

Python

```
try:
  print(1)
  #raise NameError #1,3,6
  #raise KeyError  #1,4,6
  print(2)         #1,2,5,6
except NameError:
  print(3)
except:
  print(4)
else:
  print(5)
finally:
  print(6)
print("end")
```

`finally` Clause

There is some confusion with the `finally` clause.
The code in the `finally` clause ought not change the kind of control flow: normal, exceptional, return, or break. In other words, if the block is getting ready to break out of a loop it ought not to return instead. Or, if the block is getting ready to raise an exception it ought not to break out of a loop instead.

- `except/FinReturn.java` – Java warns