Exceptions and file input/output

- try-raise-except-finally
- Exception
- control flow
- file open/read/write
- sys.stdin, sys.stdout, sys.stderr

Exceptions – Error handling and control flow

- Exceptions is a widespread technique to handle run-time **errors** / abnormal behaviour (e.g. in Python, Java, C++, JavaScript, C#)

- Exceptions can also be used as an **advanced control flow mechanism** (e.g. in Python, Java, JavaScript)

  - *Problem: How to perform a ”break” in a recursive function ?*

Built-in exceptions (class hierarchy)

```
BaseException
 +-- SystemExit
 +-- KeyboardInterrupt
 +-- GeneratorExit
 +-- Exception
      +-- StopIteration
      +-- StopAsyncIteration
      +-- ArithmeticError
      |    +-- FloatingPointError
      |    +-- OverflowError
      |    +-- ZeroDivisionError
      +-- AssertionError
      +-- AttributeError
      +-- BufferError
      +-- EOFError
      +-- ImportError
      |    +-- ModuleNotFoundError
      +-- LookupError
      |    +-- IndexError
      |    +-- KeyError
      +-- MemoryError
      +-- NameError
      |    +-- UnboundLocalError
      +-- TypeError
      +-- ValueError
      |    +-- UnicodeError
      |         +-- UnicodeDecodeError
      |         +-- UnicodeEncodeError
      |         +-- UnicodeTranslateError
      |
      +-- OSError
      |    +-- BlockingIOError
      |    +-- ChildProcessError
      |    +-- ConnectionError
      |    |    +-- BrokenPipeError
      |    |    +-- ConnectionAbortedError
      |    |    +-- ConnectionRefusedError
      |    |    +-- ConnectionResetError
      |    +-- FileExistsError
      |    +-- FileNotFoundError
      |    +-- InterruptedError
      |    +-- IsADirectoryError
      |    +-- NotADirectoryError
      |    +-- PermissionError
      |    +-- ProcessLookupError
      |    +-- TimeoutError
      +-- ReferenceError
      +-- RuntimeError
      |    +-- NotImplementedError
      |    +-- RecursionError
      +-- SyntaxError
      |    +-- IndentationError
      |         +-- TabError
      +-- SystemError
      +-- Warning
           +-- DeprecationWarning
           +-- PendingDeprecationWarning
           +-- RuntimeWarning
           +-- SyntaxWarning
           +-- UserWarning
           +-- FutureWarning
           +-- ImportWarning
           +-- UnicodeWarning
           +-- BytesWarning
           +-- ResourceWarning
```

docs.python.org/3/library/exceptions.html

Typical built-in exceptions

and unhandled behaviour

Python shell

```
> 7 / 0
| ZeroDivisionError: division by zero
> int("42x")
| ValueError: invalid literal for int() with base 10: '42x'
> x = y
| NameError: name 'y' is not defined
> L = list(range(1000000000))
| MemoryError
> 2.5 ** 1000
| OverflowError: (34, 'Result too large')
> t = (3, 4)
> t[0] = 7
| TypeError: 'tuple' object does not support item assignment
> t[3]
| IndexError: tuple index out of range
> t.x
| AttributeError: 'tuple' object has no attribute 'x'
> x = {}
> x['foo']
| KeyError: 'foo'
> def f(x): f(x + 1)
> f(0)
| RecursionError: maximum recursion depth exceeded
> def f(): x = x + 1
> f()
| UnboundLocalError: local variable 'x' referenced before assignment
```

Catching exceptions – Fractions (I)

fraction1.py

```
while True:
    numerator = int(input("Numerator = "))
    denominator = int(input("Denominator = "))
    result = numerator / denominator
    print("%s / %s = %s" % (numerator, denominator, result))
```

Python shell

```
Numerator = 10
Denominator = 3
10 / 3 = 3.3333333333333335
Numerator = 20
Denominator = 0
ZeroDivisionError: division by zero
```

Catching exceptions – Fractions (II)

catch exception

fraction2.py

```
while True:
    numerator = int(input("Numerator = "))
    denominator = int(input("Denominator = "))
    try:
        result = numerator / denominator
        print("%s / %s = %s" % (numerator, denominator, result))
    except ZeroDivisionError:
        print("cannot divide by zero")
```

Python shell

```
Numerator = 10
Denominator = 0
cannot divide by zero
Numerator = 20
Denominator = 3
20 / 3 = 6.666666666666667
Numerator = 42x
ValueError: invalid literal for int() with base 10: '42x'
```

Catching exceptions – Fractions (III)

catch exception

catch exception

fraction3.py

```
while True:
    try:
        numerator = int(input("Numerator = "))
        denominator = int(input("Denominator = "))
    except ValueError:
        print("input not a valid integer")
        continue
    try:
        result = numerator / denominator
        print("%s / %s = %s" % (numerator, denominator, result))
    except ZeroDivisionError:
        print("cannot divide by zero")
```

Python shell

```
Numerator = 5
Denominator = 2x
input not a valid integer
Numerator = 5
Denominator = 2
5 / 2 = 2.5
```

Catching exceptions – Fractions (IV)

catch exceptions

fraction4.py

```
while True:
    try:
        numerator = int(input("Numerator = "))
        denominator = int(input("Denominator = "))
        result = numerator / denominator
        print("%s / %s = %s" % (numerator, denominator, result))
    except ValueError:
        print("input not a valid integer")
    except ZeroDivisionError:
        print("cannot divide by zero")
```

Python shell

```
Numerator = 3
Denominator = 0
cannot divide by zero
Numerator = 3x
input not a valid integer
Numerator = 4
Denominator = 2
4 / 2 = 2.0
```

Keyboard interrupt (Ctrl-c)

- throws **`KeyboardInterrupt`** exception

infinite-loop1.py

```
print("starting infinite loop")

x = 0
while True:
    x = x + 1

print("done (x = %s)" % x)
input("type enter to exit")
```

Python shell

```
starting infinite loop
Traceback (most recent call last):
  File "infinite-loop1.py", line 4, in <module>
    x = x + 1
KeyboardInterrupt
```

infinite-loop2.py

```
print("starting infinite loop")

try:
    x = 0
    while True:
        x = x + 1
except KeyboardInterrupt:
    pass

print("done (x = %s)" % x)
input("type enter to exit")
```

Python shell

```
starting infinite loop
done (x = 23890363)   # Ctrl-c
type enter to exit
```

Keyboard interrupt (Ctrl-c)

- Be aware that you likely would like to leave the Ctrl-c generated **`KeyboardInterrupt`** exception unhandled, except when stated explicitly

read-int1.py

```
while True:
    try:
        x = int(input("An integer: "))
        break
    except ValueError:  # only ValueError
        continue

print("The value is:", x)
```

Python shell

```
An integer:          Ctrl-c
KeyboardInterrupt
```

read-int2.py

```
while True:
    try:
        x = int(input("An integer: "))
        break
    except:  # all exceptions
        continue

print("The value is:", x)
```

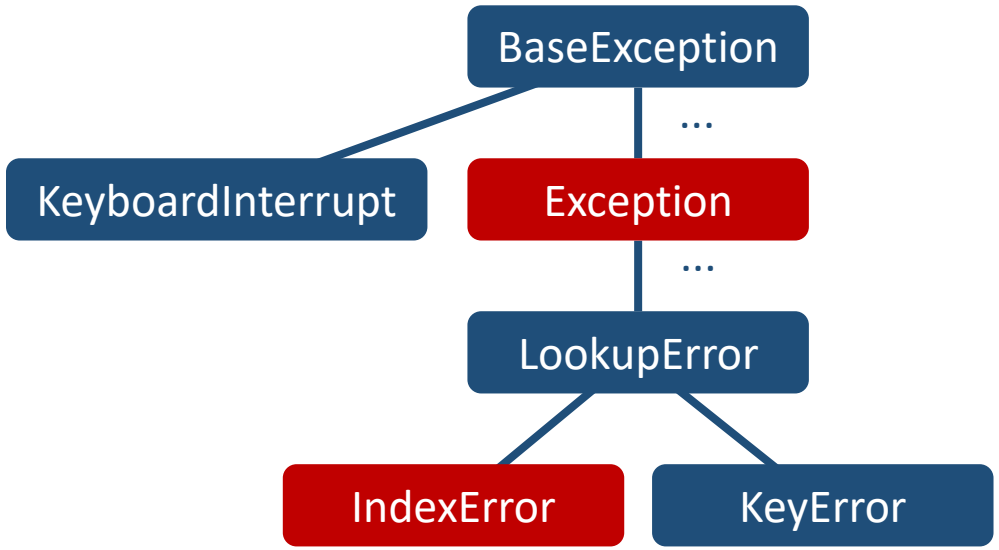
catches KeyboardInterrupt

Python shell

```
An integer:          Ctrl-c
An integer:          Ctrl-c
An integer:
```

- (left) `KeyboardInterrupt` is unhandled (right) it is handled (intentionally?)

Exception class hierarchy



except-twice1.py

```
try:
    L[4]
except IndexError:  # must be before Exception
    print("IndexError")
except Exception:
    print("Fall back exception handler")
```

except-twice2.py

```
try:
    L[4]
except Exception:  # and subclasses of Exception
    print("Fall back exception handler")
except IndexError:
    print("IndexError")  # unreachable
```

`try` statement syntax

arbitrary number of except cases

```
try:
    code
except ExceptionType1:
    code  # executed if raised exception instanceof
          # ExceptionType1 (or subclass of ExceptionType)
except ExceptionType2:
    code  # executed if exception type matches and none of
          # the previous except statements matched
...
else:
    code  # only executed if no exception was raised
finally:
    code  # always executed independent of exceptions
          # typically used to clean up (like closing files)
```

`except` variations

```
except:                         # catch all exceptions
```

```
except ExceptionType:           # only catch exceptions of class ExceptionType
                                # or subclasses of ExceptionType

except (ExceptionType1, ExceptionType2, ..., ExceptionTypek):
                                # catch any of k classes (and subclasses)

except ExceptionType as e:
                                # catch exception and assign exception object to e
                                # containing arguments to the raised exception
```

User exceptions

- New exception types are created using class inheritance from an existing exception type (possibly defining __init__)

- An exception is raised using one of the following (the first being an alias for the second):

```
raise ExceptionType
raise ExceptionType()
raise ExceptionType(args)
```

tree-search.py

```
class SolutionFound(Exception): # new exception
    pass

def recursive_tree_search(x, t):
    if isinstance(t, tuple):
        for child in t:
            recursive_tree_search(x, child)
    elif x == t:
        raise SolutionFound  # found x in t

def tree_search(x, t):
    try:
        recursive_tree_search(x, t)
    except SolutionFound:
        print("found", x)
    else:
        print("search for", x, "unsuccessful")
```

Python shell

```
> tree_search(8, ((3,2),5,(7,(4,6))))
| search for 8 unsuccessful
> tree_search(3, ((3,2),5,(7,(4,6))))
| found 3
```

3 ways to read lines from a file

Steps

1. Open file using `open`
2. Read lines from file using
   a) *`filehandler`*`.readline`
   b) *`filehandler`*`.readlines`
   c) `for` *`line`* `in` *`filehandler`*`:`
3. Close file using `close`

try to open file for reading

filename

filehandle

iterate over lines in file

close file when done

reading-file1.py

```
f = open('reading-file1.py')
for line in f:
    print(">", line[:-1])
f.close()
```

read all lines into a list of strings

reading-file2.py

```
f = open('reading-file2.py')
lines = f.readlines()
for line in lines:
    print(">", line[:-1])
f.close()
```

read single line (terminated by '\n')

reading-file3.py

```
f = open('reading-file3.py')
line = f.readline()
while line != "":
    print(">", line[:-1])
    line = f.readline()
f.close()
```

3 ways to write lines to a file

try to open file for writing

write mode

write single string to file

write list of strings to file

append to existing file

factorial.py

```
f = open('output-file.txt', 'w')
f.write('Text 1\n')
f.writelines(['Text 2\n', 'Text 3 '])
f.close()

g = open('output-file.txt', 'a')
g.write('Text 4\n')
g.writelines(['Text 5 ', 'Text 6'])
g.close()
```

output-file.txt

```
Text 1
Text 2
Text 3 Text 4
Text 5 Text 6
```

- Opening file:
  `open(`*`filename`*`, `*`mode`*`)`
  where *`mode`* is a string, either `'w'` for opening a new (or truncating an existing file) and `'a'` for appending to an existing file
- Write single string:
  `filehandle``.write(`*`string`*`)`
- Write list of strings strings:
  `filehandle``.writeline(`*`list`*`)`
- Newlines (`'\n'`) must be written explicitly

Exceptions while dealing with files

- When dealing with files one should be prepared to handle errors / raised exceptions, e.g. `FileNotFoundError`

reading-file4.py

```
try:
    f = open('reading-file4.py')
except FileNotFoundError:
    print("Could not open file")
else:
    try:
        for line in f:
            print("> ", line[:-1])
    finally:
        f.close()
```

Opening files using `with`

- The Python keyword **`with`** allows to create a *context manager* for handling files
- *Filehandle will automatically be closed, also when exceptions occur*
- Under the hood: filehandles returned by `open()` support `__enter__()` and `__exit__()` methods

f = result of calling `__enter__()` on result of `open` expression, which is the file handle

reading-file5.py

```
with open('reading-file5.py') as f:
    for line in f:
        print("> ", line[:-1])
```

Does a file exist?

- Module `os.path` contains a method `isfile` to check if a file exists

checking-files.py

```
import os.path

filename = input("Filename: ")
if os.path.isfile(filename):
    print("file exists")
else:
    print("file does not exists")
```

docs.python.org/3/library/os.path.html

module `sys`

- Module `sys` contains the three standard file handles
  - `sys.stdin` (used by the `input` function)
  - `sys.stdout` (used by the `print` function)
  - `sys.stderr` (error output from the Python interpreter)

sys-test.py

```
import sys
sys.stdout.write("Input an integer: ")
x = int(sys.stdin.readline())
sys.stdout.write("%s square is %s" % (x, x**2))
```

Python shell

```
Input an integer: 10
10 square is 100
```

docs.python.org/3/library/sys.html

PEP8 on exceptions

- For all try/except clauses, limit the try clause to the absolute minimum amount of code necessary.
- The class naming convention applies (CapWords)
- Use the suffix "Error" on your exception names (if the exception actually is an error)
- A bare `except:` clause will catch `SystemExit` and `KeyboardInterrupt` exceptions, making it harder to interrupt a program with Control-C, and can disguise other problems. If you want to catch all exceptions that signal program errors, use `except Exception:`

www.python.org/dev/peps/pep-0008/