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)

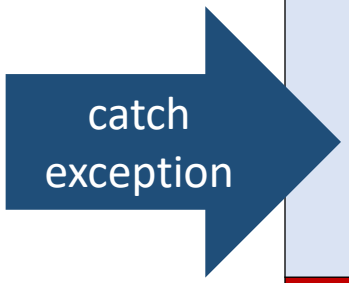
fraction1.py

```
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)



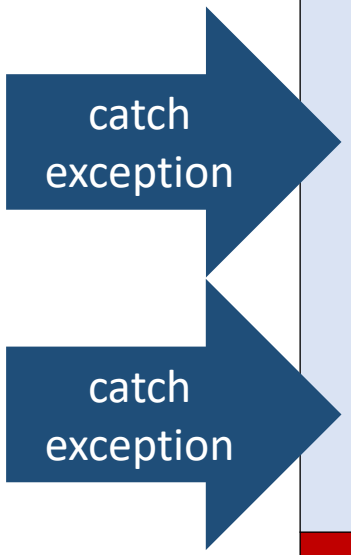
fraction2.py

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

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)



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
    except ZeroDivisionError:
        print('cannot divide by zero')
        continue
    print('%s / %s = %s' % (numerator, denominator, result))
```

Python shell

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

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 = 1000000000000000000000000000000000000000000000000000000000
  0000000000000000000000000000000000000000000000000000000000000000000000
  0000000000000000000000000000000000000000000000000000000000000000000000
  0000000000000000000000000000000000000000000000000000000000000000000000
  000000000000000000000000000000000000000000
| Denominator = 1
| OverflowError: integer division result too large for a float
```

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)
```

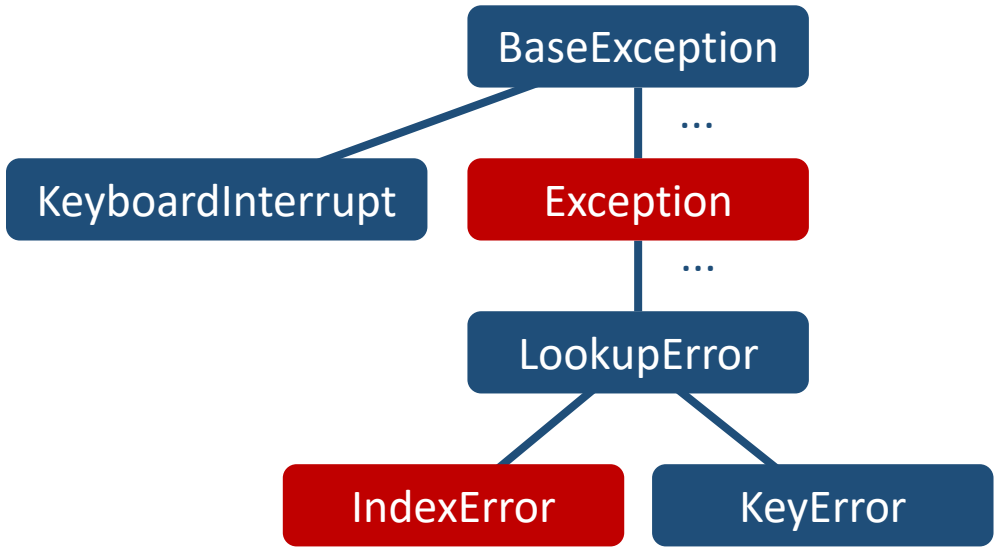
catches KeyboardInterrupt

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 ExceptionType1)
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
                                # e.args contains arguments to the raised exception
```

Raising exceptions

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

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

abstract.py

```
class A():
      def f(self):
          print('f')
          self.g()
      def g(self):
          raise NotImplementedError
class B(A):
      def g(self):
          print('g')
```

Python shell

```
> B().f()
| f
| g
> A().f()
| f
| NotImplementedError
```

User exceptions

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

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(7, ((3,2),5,(7,(4,6))))
| found 7
```

User exception with argument in recursion

- Escape from recursion by raising exception
- Pass result as argument to exception
- Unpack `.args` tuple from result caught by `except`

apx-tree-search.py

```
class SolutionFound(Exception):
    pass

def apx_tree_search(x, tree):
    def search(x, t):
        if isinstance(t, tuple):
            for child in t:
                search(x, child)
        elif abs(x - t) < 1:  # approximate match
            raise SolutionFound(t)

    try:
        search(x, tree)
    except SolutionFound as e:
        result, = e.args  # e.args is a tuple
        print('search for', x, 'found', result)
    else:
        print('search for', x, 'unsuccessful')

tree = ((3.2, 2.1), 5.6, (7.8, (9.3, 6.5)))
apx_tree_search(4.3, tree)
apx_tree_search(5.9, tree)
```

Python shell

```
search for 4.3 unsuccessful
search for 5.9 found 5.6
```

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`

`open ('filename.txt')` assumes the file to be in the same folder as your Python program, but you can also provide a full path `open('c:/Users/gerth/Documents/filename.txt')`

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()
f.close()
for line in lines:
    print('>', line[:-1])
```

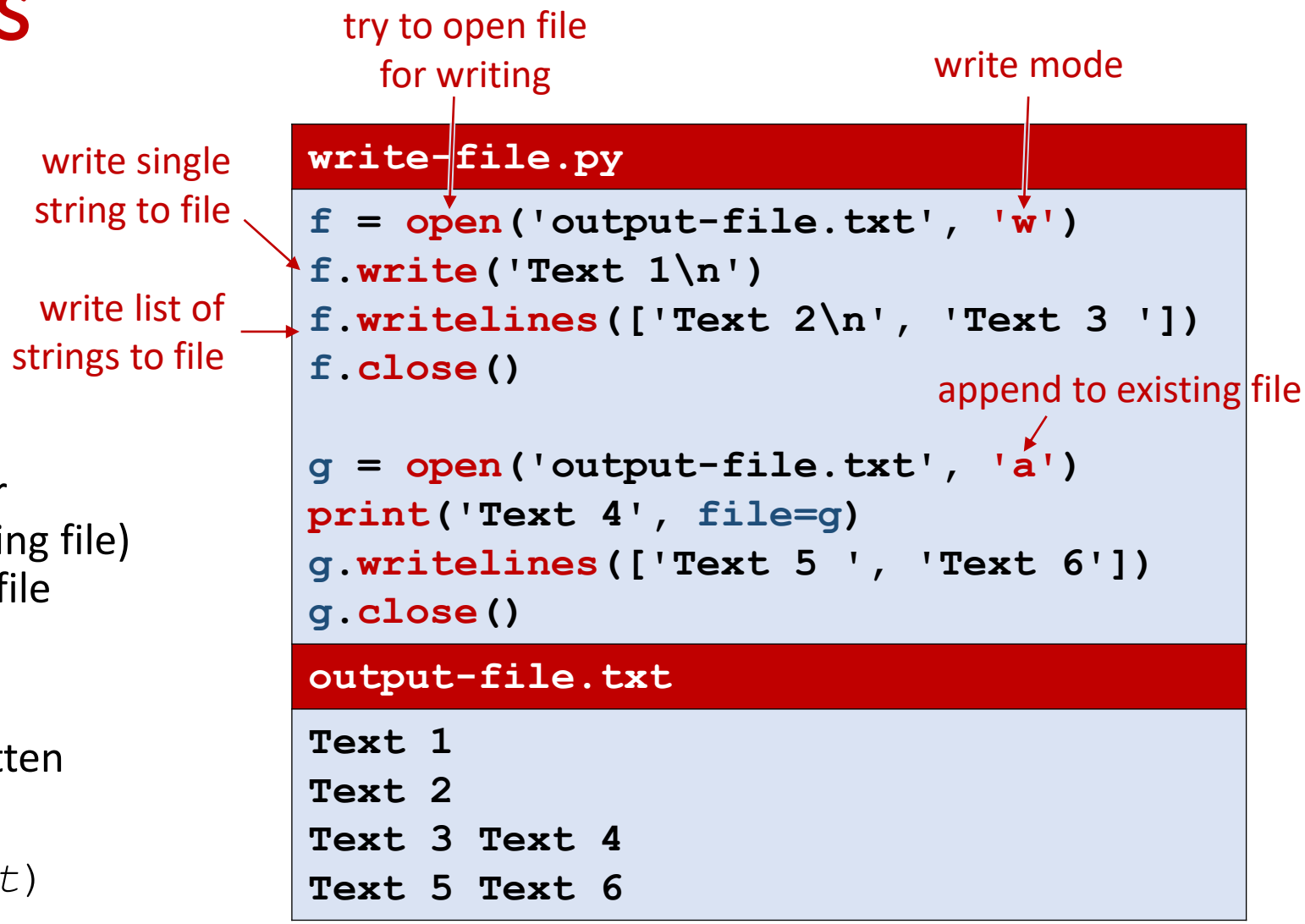
read single line (terminated by '\n')

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

- 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`*`)`
  Returns the number of characters written
- Write list of strings strings:
  `filehandle``.writeline(`*`list`*`)`
- Newlines (`'\n'`) must be written explicitly
- `print` can take an optional `file` argument



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

print(..., file=*output file*)

sys-print-file.py

```
import sys
def complicated_function(file):
    print('Hello world', file=file)  # print to file or STDOUT
while True:
    file_name = input('Output file (empty for STDOUT): ')

    if file_name == '':
        file = sys.stdout
        break
    else:
        try:
            file = open(file_name, 'w')
            break
        except Exception:
            pass
complicated_function(file)
if file != sys.stdout:
    file.close()
```

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/

Performance of scanning a file

- Python can efficiently scan through quite big files

File	Size	Time
Atom_chem_shift.csv	≈ 750 MB	≈ 8 sec
cano.txt	≈ 3.7 MB	≈ 0.1 sec

The first search finds all lines related to ThrB12-DKP-insulin (Entry ID 6203) in a chemical database available from www.bmrb.wisc.edu

The second search finds all occurrences of “Germany” in Conan Doyle's complete Sherlock Holmes available at sherlock-holm.es

file-scanning.py

```
from time import time

for filename, query in [
        ('Atom_chem_shift.csv', ',6203,'),
        ('cano.txt', 'Germany')
    ]:
    count = 0
    matches = []
    start = time()
    with open(filename) as f:
        for i, line in enumerate(f, start=1):
            count += 1
            if query in line:
                matches.append((i, line))
    end = time()

    for i, line in matches:
        print(i, ':', line, end='')
    print('Duration:', end - start)
    print(len(matches), 'of', count, 'lines match')
```

Python shell

```
...
3057752 : 195,,2,2,30,30,THR,HB,H,1,4.22,0.02,,1,,,,,,,,,,,,,,,,,,,,228896,6203,2
3057753 : 196,,2,2,30,30,THR,HG21,H,1,1.18,0.02,,1,,,,,,,,,,,,,,,,,,,,228896,6203,2
3057754 : 197,,2,2,30,30,THR,HG22,H,1,1.18,0.02,,1,,,,,,,,,,,,,,,,,,,,228896,6203,2
3057755 : 198,,2,2,30,30,THR,HG23,H,1,1.18,0.02,,1,,,,,,,,,,,,,,,,,,,,228896,6203,2
Duration: 7.760039329528809
329 of 9758361 lines match
57557 :      "Well, then, to the West, or to England, or to Germany, where father
66515 :      kind master. He wanted me to go with his wife to Germany yesterday,
66642 :      of business in Germany in the past and my name is probably familiar
73273 :      associates with Germany. This he placed in his instrument cupboard.
Duration: 0.07700657844543457
4 of 76764 lines match
```

sudoku.py

```
class Sudoku:
  def __init__(self, puzzle):
    self.puzzle = puzzle

  def solve(self):
    def find_free():
      for i in range(9):
        for j in range(9):
          if self.puzzle[i][j] == 0:
            return (i, j)
      return None

    def unused(i, j):
      i_, j_ = i // 3 * 3, j // 3 * 3
      cells = {(i, k) for k in range(9)}
      cells |= {(k, j) for k in range(9)}
      cells |= {(i, j) for i in range(i_, i_ + 3)
                       for j in range(j_, j_ + 3)}
      return set(range(1, 10)) - {self.puzzle[i][j] for i, j in cells}

    class SolutionFound(Exception):
      pass

    def recursive_solve():
      cell = find_free()
      if not cell:
        raise SolutionFound
      i, j = cell
      for value in unused(i, j):
        self.puzzle[i][j] = value
        recursive_solve()
      self.puzzle[i][j] = 0

    try:
      recursive_solve()
    except SolutionFound:
      pass
```

sudoku.py (*continued*)

```
  def print(self):
    for i, row in enumerate(self.puzzle):
      cells = [' %s ' % c if c else ' . ' for c in row]
      print('|'.join(['''.join(cells[j:j+3]) for j in (0,3,6)]))
      if i in (2,5):
        print('---------+---------+---------')

with open('sudoku.txt') as f:
    A = Sudoku([[int(x) for x in line.strip()] for line in f])

A.solve()
A.print()
```

sudoku.txt

```
517600034
289004000
346205090
602000010
038006047
000000000
090000078
703400560
000000000
```

Python shell

```
|  5  1  7 | 6  9  8 | 2  3  4
|  2  8  9 | 1  3  4 | 7  5  6
|  3  4  6 | 2  7  5 | 8  9  1
| ---------+---------+---------
|  6  7  2 | 8  4  9 | 3  1  5
|  1  3  8 | 5  2  6 | 9  4  7
|  9  5  4 | 7  1  3 | 6  8  2
| ---------+---------+---------
|  4  9  5 | 3  6  2 | 1  7  8
|  7  2  3 | 4  8  1 | 5  6  9
|  8  6  1 | 9  5  7 | 4  2  3
```