Working with text

- file formats
- CSV, JSON, XML, Excel
- regular expressions
- module re, finditer

Some file formats

File extension	Content
.html	HyperText Markup Language
.mp3	Audio File
.png .jpeg .jpg	Image files
.svg	Scalable Vector Graphics file
.json	JavaScript Object Notation
.csv	Comma separated values
.xml	eXtensible Markup Language
.xlmx	Micosoft Excel 2010/2007 Workbook

File extension	Description
.exe	Windows executable file
.app	Max OS X Application
.py	Python program
.pyc	Python compiled file
.java	Java program
.cpp	C++ program
.c	C program
.txt	Raw text file

PIL – the Python Imaging Library

- pip install Pillow

```
rotate_image.py
from PIL import Image
img = Image.open('Python-Logo.png')
img_out = img.rotate(45, expand=True)
img_out.save('Python-rotated.png')
```

- For many file types there exist Python packages handling such files, e.g. for images Pillow supports 40+ different file formats
- For more advanced computer vision tasks you should consider OpenCV

Python-Logo.png

Python-rotated.png

python-pillow.org

CSV files - Comma Separated Values

- Simple 2D tables are stored as rows in a file, with values separated by comma
- Strings stored are quoted if necessary
- Values read are strings
- The deliminator (default comma) can be changed by keyword argument `delimiter`.
  Other typical deliminators are tabs '`\t`', and semicolon '`;`'

csv-example.py

```
import csv
FILE = 'csv-data.csv'
data = [[1, 2, 3],
        ['a', '"b"'],
        [1.0, ['x',"y"], 'd']]

with open(FILE, 'w', newline='') as outfile:
    csv_out = csv.writer(outfile)
    for row in data:
        csv_out.writerow(row)

with open(FILE, 'r', newline='') as infile:
    for row in csv.reader(infile):
        print(row)
```

Python shell

```
['1', '2', '3']
['a', '"b"']
['1.0', "['x', 'y']", 'd']
```

csv-data.csv

```
1,2,3
a,""b""
1.0,"['x', 'y']",d
```

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

CSV files - Tab Separated Values

csv-tab-separated.py

```
import csv

FILE = 'tab-separated.csv'

with open(FILE) as infile:
    for row in csv.reader(infile, delimiter='\t'):
        print(row)
```

Python shell

```
['1', '2', '3']
['4', '5', '6']
['7', '8', '9']
```

tab-separated.csv

```
1	2	3
4	5	6
7	8	9
```

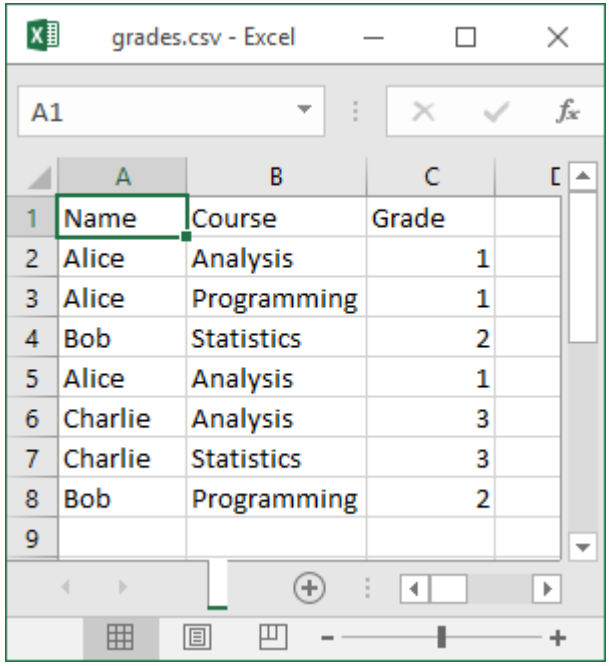
Reading an Excel generated CSV file

average.py

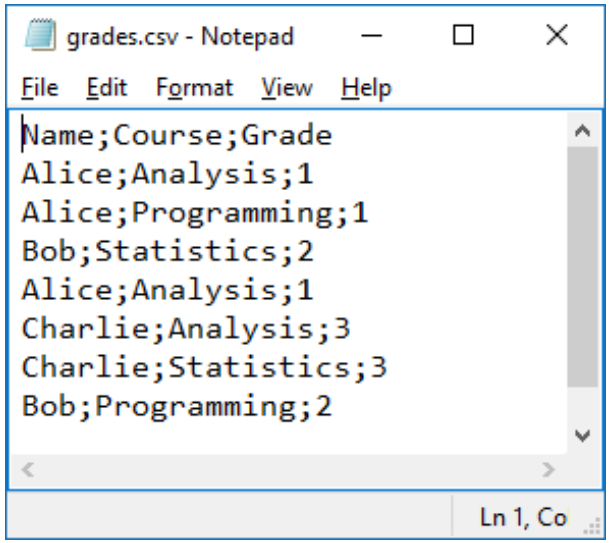
```
import csv

with open('grades.csv') as file:
    data = csv.reader(file, delimiter=';')  # data = iterator over the rows
    header = next(data)                     # ['Name', 'Course', 'Grade']
    count = {}
    total = {}
    for row in data:                        # iterate over data rows
        course = row[header.index('Course')]
        grade  = int(row[header.index('Grade')])
        count[course] = count.get(course, 0) + 1
        total[course] = total.get(course, 0) + grade
print('Average grades:')
width = max(map(len, count))  # maximum course name length
for course in count:
    print(f'{course:>{width}s} : {total[course] / count[course]:.2f}')
```

Python shell

```
Average grades:
   Analysis : 1.67
Programming : 1.50
 Statistics : 2.50
```



Saving a file in Excel as
CSV (Comma delimited) (*.csv)
Sometimes use ';' as default separator,
determined by Windows Regional settings



CSV files - Quoting

- The amount of quoting is controlled with keyword argument **`quoting`**
- `csv.QUOTE_MINIMAL` etc. can be used to select the quoting level
- Depending on choice of quoting, numeric values and strings cannot be distinguished in CSV file (`csv.reader` will read all as strings anyway)

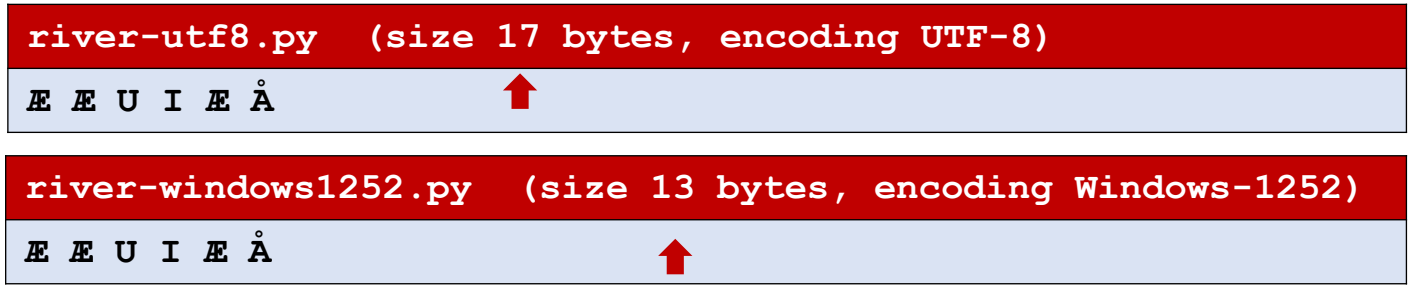
csv-quoting.py

```
import csv
import sys

data = [[1, 1.0, '1.0'], ['abc', '"', '\t"', ',']]

quoting_options = [(csv.QUOTE_MINIMAL,    'QUOTE_MINIMAL'),
                   (csv.QUOTE_ALL,        'QUOTE_ALL'),
                   (csv.QUOTE_NONNUMERIC, 'QUOTE_NONNUMERIC'),
                   (csv.QUOTE_NONE,       'QUOTE_NONE')]

for quoting, name in quoting_options:
    print(name)
    csv_out = csv.writer(sys.stdout, quoting=quoting, escapechar='\\')
    for row in data:
        csv_out.writerow(row)
```

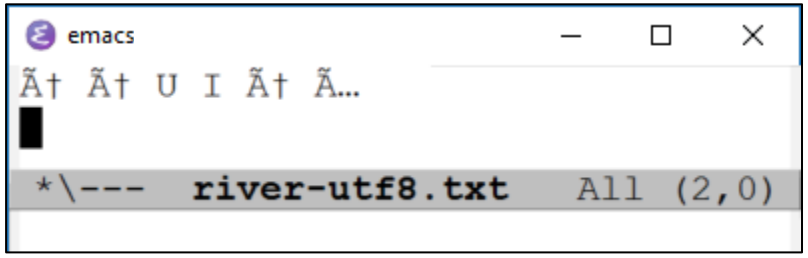
Python shell

```
QUOTE_MINIMAL  # cannot distinguish 1.0 and "1.0"
1,1.0,1.0
abc,""""," """,","
QUOTE_ALL  # cannot distinguish 1.0 and "1.0"
"1","1.0","1.0"
"abc",""""," """,","
QUOTE_NONNUMERIC
1,1.0,"1.0"
"abc",""""," """,","
QUOTE_NONE  # cannot distinguish 1.0 and "1.0"
1,1.0,1.0
abc,\",       \",\,
```

File encodings...



- Text files can be *encoded* using many different encodings (UTF-8, UTF-16, UTF-32, Windows-1252, ANSI, ASCII, ISO-8859-1, ...)
- Different encodings can result in different file sizes, in particular when containing non-ASCII symbols
- Programs often try to predict the encoding of text files (often with success, but not always)
- Opening files assuming wrong encoding can give strange results....



Opening UTF-8 encoded file but trying to decode using Windows-1252

Opening Windows-1252 encoded file but trying to decode using UTF-8

en.wikipedia.org/wiki/Character_encoding

encoding.py

```
for filename in ['river-utf8.txt', 'river-windows1252.txt']:
    print(filename)
    f = open(filename, 'rb')  # open input in binary mode, default = text mode = 't'
    line = f.readline()       # type(line) = bytes = immutable list of integers in 0..255
    print(line)                                  # byte literals look like strings, prefixed 'b'
    print(list(line))                            # print bytes as list of integers
    f = open(filename, 'r', encoding='utf-8')  # try to open file as UTF-8
    line = f.readline()                          # fails if input line is not utf-8
    print(line)
```

river-utf8.py

```
Æ Æ U I Æ Å
```

Python shell

```
| river-utf8.txt
| b'\xc3\x86 \xc3\x86 U I \xc3\x86 \xc3\x85\r\n'  # \x = hexadecimal value follows
| [195, 134, 32, 195, 134, 32, 85, 32, 73, 32, 195, 134, 32, 195, 133, 13, 10]
| Æ Æ U I Æ Å

| river-windows1252.txt
| b'\xc6 \xc6 U I \xc6 \xc5\r\n'
| [198, 32, 198, 32, 85, 32, 73, 32, 198, 32, 197, 13, 10]
| UnicodeDecodeError: 'utf-8' codec can't decode byte 0xc6 in position 0: invalid continuation
  byte

> 'Æ Æ U I Æ Å'.encode('utf8')  # convert string to (an immutable array of) bytes
| b'\xc3\x86 \xc3\x86 U I \xc3\x86 \xc3\x85'
> 'Æ Æ U I Æ Å'.encode('utf8').decode('Windows-1252')  # decode bytes to string
| 'Ã† Ã† U I Ã† Ã…'
```

Reading CSV files with specific encoding

read_shopping.py

```
import csv

with open('shopping.csv', encoding='Windows-1252') as file:
    for article, amount in csv.reader(file):
        print('Buy', amount, article)
```

Python shell

```
Buy 2 æbler
Buy 4 pærer
Buy 3 jordbær
Buy 10 gulerødder
```

shopping.csv

```
æbler,2
pærer,4
jordbær,3
gulerødder,10
```

CSV file saved with Windows-1252 encoding

JSON

*"**JSON** (**J**ava**S**cript **O**bject **N**otation) is a lightweight data-interchange format. It is easy for humans to read and write. It is easy for machines to parse and generate. It is based on a subset of the JavaScript Programming Language, Standard ECMA-262 3rd Edition - December 1999. JSON is an ideal data-interchange language."*

www.json.org

- Human readable file format
- Easy way to save a Python expression to a file
- Does *not* support all Python types, e.g. sets are not supported, and tuples are saved (and later loaded) as lists

JSON example

json-example.py

```
import json
FILE = 'json-data.json'
data = ((None, True), (42.7, (42,)), [3, 2, 4], (5, 6, 7),
        {'b':'banana', 'a':'apple', 'c': 'coconut'})

with open(FILE, 'w') as outfile:
    json.dump(data, outfile, indent=2, sort_keys=True)

with open(FILE) as infile:
    indata = json.load(infile)

print(indata)
```

Python shell

```
[[None, True], [42.7, [42]], [3, 2, 4], [5, 6, 7], {'a':
'apple', 'b': 'banana', 'c': 'coconut'}]
```

json-data.json

```
[
  [
    null,
    true
  ],
  [
    42.7,
    [
      42
    ]
  ],
  [
    3,
    2,
    4
  ],
  [
    5,
    6,
    7
  ],
  {
    "a": "apple",
    "b": "banana",
    "c": "coconut"
  }
]
```

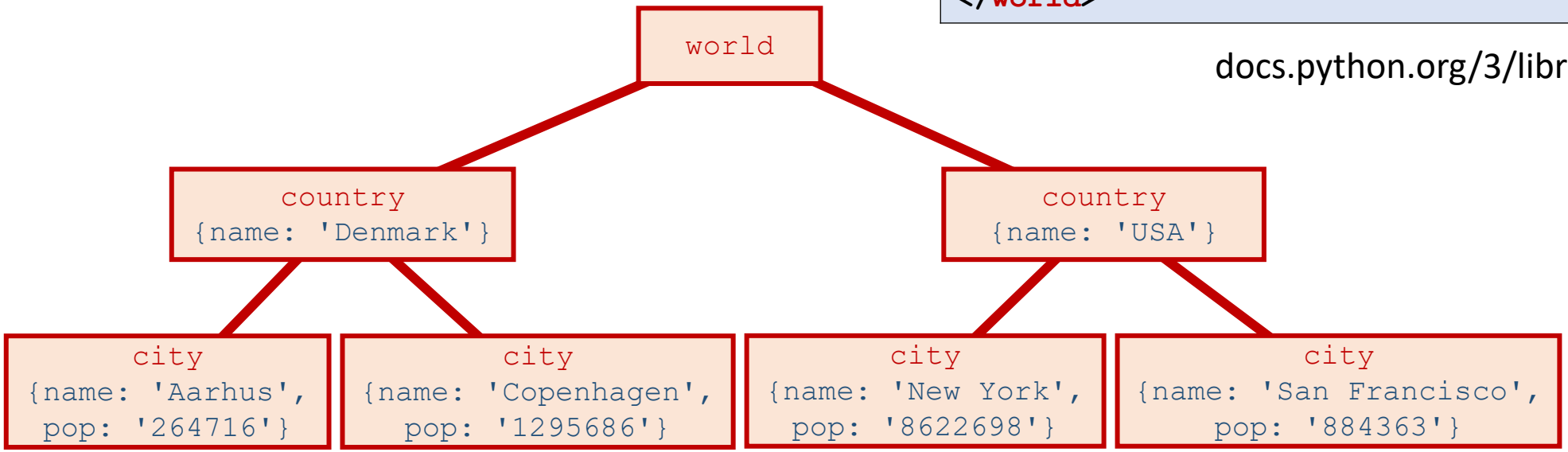
XML - eXtensible Markup Language

- XML is a widespread used data format to store hierarchical data with tags and attributes

cities.xml

```
<?xml version="1.0"?>
<world>
  <country name="Denmark">
    <city name="Aarhus" pop="264716"/>
    <city name="Copenhagen" pop="1295686"/>
  </country>
  <country name="USA">
    <city name="New York" pop="8622698"/>
    <city name="San Francisco" pop="884363"/>
  </country>
</world>
```

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



xml-example.py

```
import xml.etree.ElementTree as ET
FILE = 'cities.xml'
tree = ET.parse(FILE)  # parse XML file to internal representation
root = tree.getroot()  # get root element
for country in root:
    for city in country:
        print(city.attrib['name'],  # get value of attribute for an element
              'in',
              country.attrib['name'],
              'has a population of',
              city.attrib['pop'])
print(root.tag, root[0][1].attrib)  # the tag & indexing the children of an element
print([city.attrib['name'] for city in root.iter('city')])  # .iter finds elements
```

Python shell

```
Aarhus in Denmark has a population of 264716
Copenhagen in Denmark has a population of 1295686
New York in USA has a population of 8622698
San Francisco in USA has a population of 884363
world {'name': 'Copenhagen', 'pop': '1295686'}
['Aarhus', 'Copenhagen', 'New York', 'San Francisco']
```

cities.xml

```
<?xml version="1.0"?>
<world>
  <country name="Denmark">
    <city name="Aarhus" pop="264716"/>
    <city name="Copenhagen" pop="1295686"/>
  </country>
  <country name="USA">
    <city name="New York" pop="8622698"/>
    <city name="San Francisco" pop="884363"/>
  </country>
</world>
```

XML tags with text

city-descriptions.xml

```
<?xml version="1.0"?>
<world>
  <country name="Denmark">
    <city name="Aarhus" pop="264716">The capital of Jutland</city>
    <city name="Copenhagen" pop="1295686">The capital of Denmark</city>
  </country>
  <country name="USA">
    <city name="New York" pop="8622698">Known as Big Apple</city>
    <city name="San Francisco" pop="884363">Home of the Golden Gate Bridge</city>
  </country>
</world>
```

xml-descriptions.py

```
import xml.etree.ElementTree as ET
FILE = 'city-descriptions.xml'
tree = ET.parse(FILE)
root = tree.getroot()

for city in root.iter('city'):
    print(city.get('name'), '-', city.text)
```

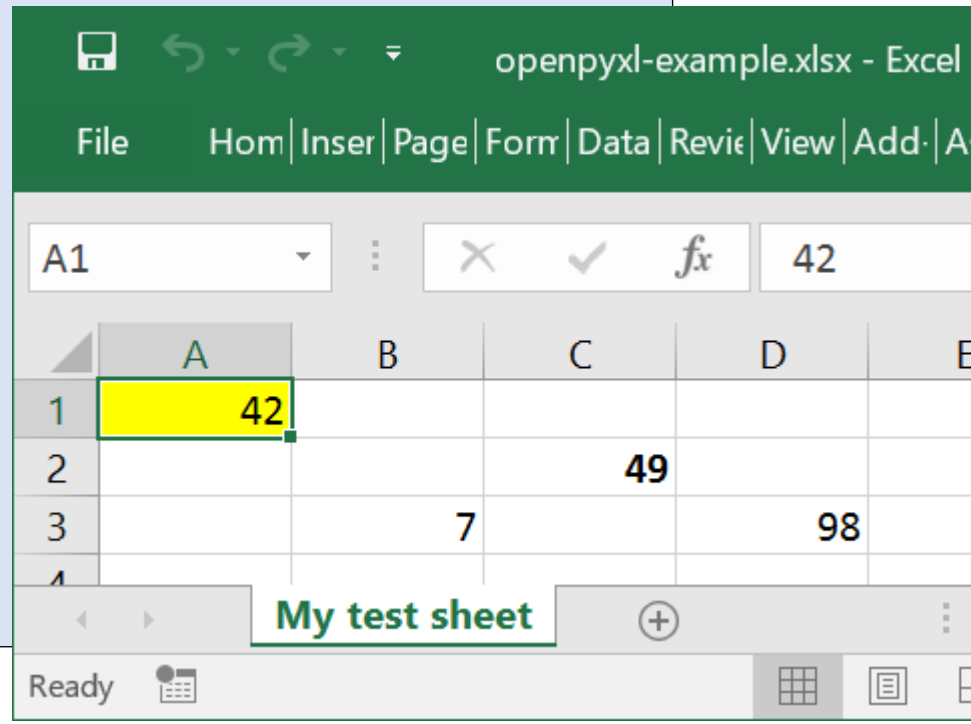
Python shell

```
Aarhus - The capital of Jutland
Copenhagen - The capital of Denmark
New York - Known as Big Apple
San Francisco - Home of the Golden Gate Bridge
```

Openpyxl - Microsoft Excel 2010 manipulation

openpyxl-example.py

```
from openpyxl import Workbook
from openpyxl.styles import Font, PatternFill

wb = Workbook()  # create workbook
ws = wb.active   # active worksheet

ws['A1'] = 42
ws['B3'] = 7
ws['C2'] = ws['A1'].value + ws['B3'].value
ws['D3'] = '=A1+B3+C2'

ws.title = 'My test sheet'

ws['A1'].fill = PatternFill('solid', fgColor='ffff00')
ws['C2'].font = Font(bold=True)

wb.save('openpyxl-example.xlsx')
```



openpyxl.readthedocs.io/en/stable/tutorial.html

String searching using `find`

- Search for first occurence of *substring* in *str*[*start*, *end*]

  str.find(*substring*[, *start*[, *end*]])
- Returns -1 if no occurence found.
- .index similar as .find, except raises ValueError exception if substring not found

string-search.py

```
text = 'this is a string - a list of characters'
pattern = 'is'

idx = text.find(pattern)
while idx >= 0:
    print(idx, end=' ')
    idx = text.find(pattern, idx + 1)
```

Python shell

```
2 5 22
```

docs.python.org/3/library/stdtypes.html#textseq

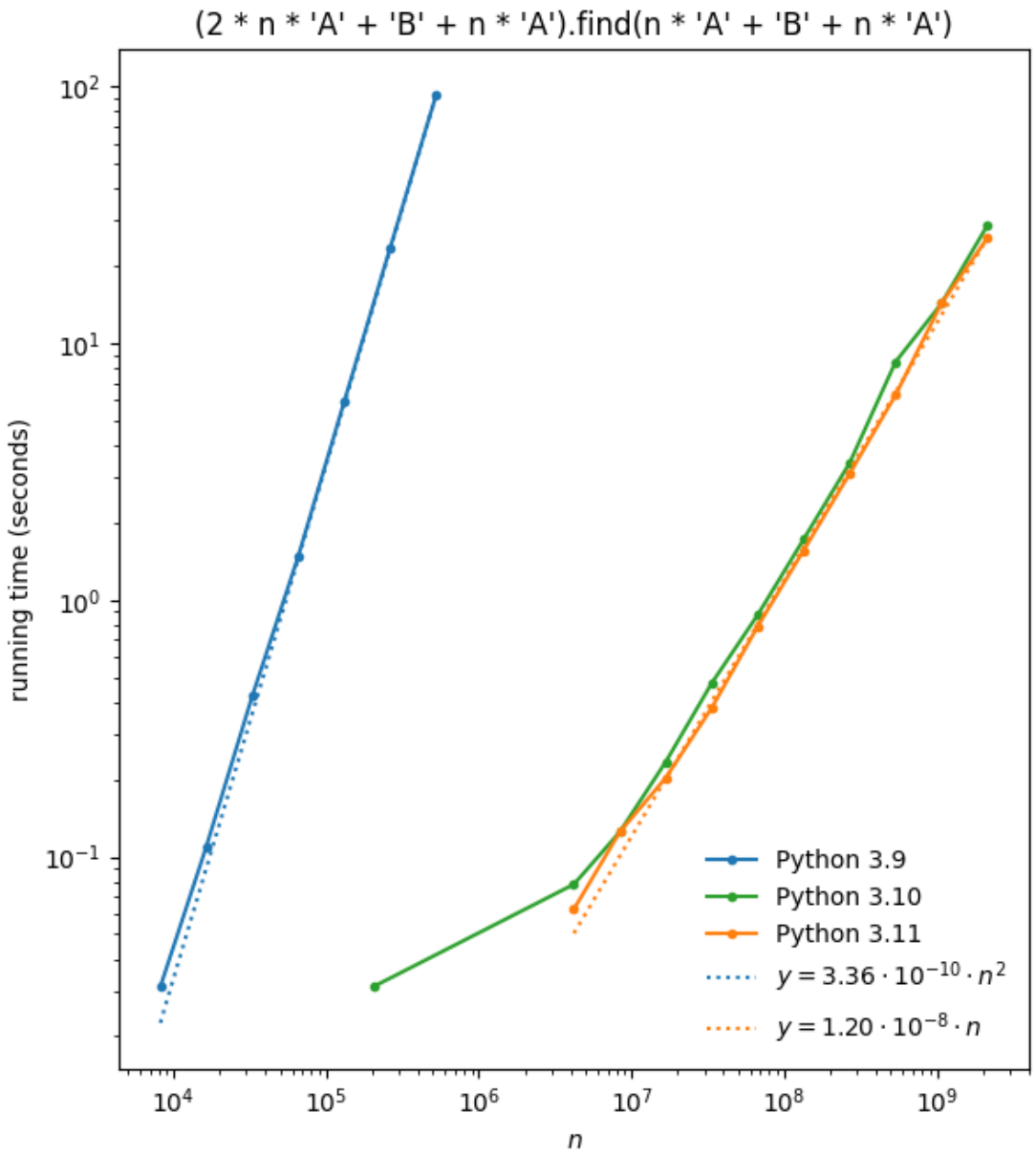
Is *str*.find fast?

- Typically linear
- Until Python 3.9 in some cases quadractic

  `"A`^{2n}`BA`^{n}`".find("A`^{n}`BA`^{n}`")`

- docs.python.org/3/whatsnew/3.10.html

  "Substring search functions such as str1 in str2 and str2.find(str1) now sometimes use Crochemore & Perrin's "Two-Way" string searching algorithm to avoid quadratic behavior on long strings."



Regular expression
– A powerful language to describe sets of strings

- **Examples**
  - `abc` denotes a string of letters
  - `ab*c` any string starting with `a`, followed by an arbitrary number of `b`s and terminated by `c`, i.e. {`ac`, `abc`, `abbc`, `abbbc`, `abbbbc`, ...}
  - `ab+c` equivalent to `abb*c`, i.e. there must be at least one `b`
  - `a\wc` any three letter string, starting with `a` and ending with `c`, where second character is any character in `[a-zA-Z0-9_]`
  - `a[xyz]c` any three letter string, starting with `a` and ending with `c`, where second character is either `x`, `y` or `z`
  - `a[^xyz]c` any three letter string, starting with `a` and ending with `c`, where second character is *none* of `x`, `y` or `z`
  - `^xyz` match at start of string (prefix)
  - `xyz$` match at end of string (suffix)
  - ...
- See docs.python.org/3/library/re.html for more

String searching using regular expressions

- `re.search(pattern, text)`
  - find the first occurence of *`pattern`* in *`text`* – returns `None` or a *match object*
- `re.findall(pattern, text)`
  - returns a list of non-overlapping occurence of *`pattern`* in *`text`* – returns a list of substrings
- `re.finditer(pattern, text)`
  - iterator returning a match object for each non-overlapping occurence of *`pattern`* in *`text`*

Python shell

```
> import re
> text = 'this is a string - a list of characters'
> re.findall(r'i\w*', text)  # prefix with 'r' for raw string literal
| ['is', 'is', 'ing', 'ist']
> for m in re.finditer(r'a[^at]*t', text):  # m is a match object
      print(f'text[{m.start()}, {m.end()}] = {m.group()}')
| text[8, 12] = a st
  text[19, 25] = a list
  text[33, 36] = act
```

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

Substitution and splitting using regular expressions

- `re.sub(`*`pattern`*`, `*`replacement`*`, `*`text`*`)`
  - replace any occurence of the *`pattern`* in *`text`* by *`replacement`*
- `re.split(`*`pattern`*`, `*`text`*`)`
  - split *`text`* at all occurences of *`patern`*

Python shell

```
> text = 'this is a string - a list of characters'
> re.sub(r'\w*i\w*', 'X', text)  # replace all words containing i by 'X'
| 'X X a X - a X of characters'
> re.sub(r'\w*i\w*', lambda m: m.group()[::-1], text)  # reverse words containing i
| 'siht si a gnirts - a tsil of characters'
> re.split(r'[^\w]+a[^\w]+', text)  # split around word 'a'
| ['this is', 'string', 'list of characters']
```

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

Regular expression substitution: \b \w \1 \2 …

- Assume we want to replace ”a” with ”an” in front of words starting with the vowels a, e, i, o and u.

Python shell

```
> txt = 'A elephant, a zebra and a ape'   # two places to correct
> re.sub('a', 'an', txt)                  # same as txt.replace('a', 'an')
| 'A elephannt, an zebran annd an anpe'   # replaces all letters 'a' with 'an'
> re.sub(r'\ba\b', 'an', txt)             # raw string + \b boundary of word
| 'A elephant, an zebra and an ape'       # all lower 'a' replaced
> re.sub(r'\b[aA]\b', 'an', txt)
| 'an elephant, an zebra and an ape'      # both 'a' and 'A' replaced by 'an'
> re.sub(r'\b([aA])\b', r'\1n', txt)      # use () and \1 to reinsert match
| 'An elephant, an zebra and an ape'      # kept 'a' and 'A'
> re.sub(r'\b([aA])\s+[aeiou]', r'\1n', txt)      # \s+ = one or more whitespace
| 'Anlephant, a zebra and anpe'           # missing original whitespace + vowel
> re.sub(r'\b([aA])(\s+[aeiou])', r'\1n\2', txt)  # reinsert both () using \1 \2
| 'An elephant, a zebra and an ape'
```

Fun with strings: Lindenmayer systems (L-systems)

Axiom A

(1)	AB
(2)	ABA
(3)	ABAAB
(4)	ABAABABA

Rules

A → AB

B → A

First four iterations of parallel rewriting

"L-systems were introduced and developed in 1968 by Aristid Lindenmayer, a Hungarian theoretical biologist and botanist at the University of Utrecht. Lindenmayer used L-systems to describe the behaviour of plant cells and to model the growth processes of plant development."

- Wikipedia

L_system.py

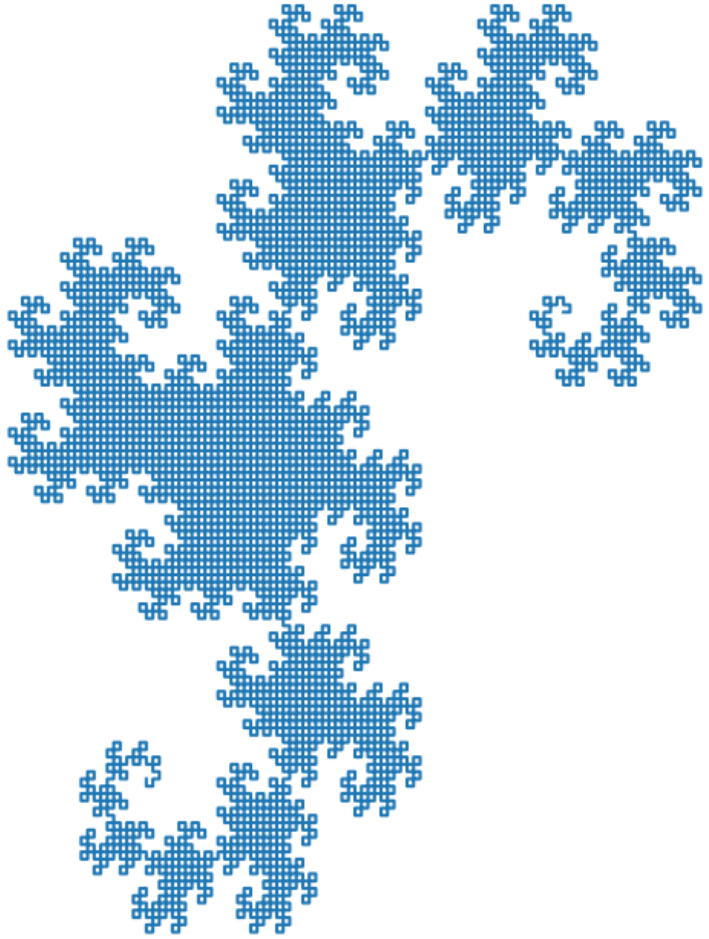
```
S = 'A'  # axiom
rules = {'A': 'AB', 'B': 'A'}
for i in range(8):
    S = ''.join(rules.get(c, c) for c in S)
    print(S)
```

Python shell

```
AB
ABA
ABAAB
ABAABABA
ABAABABAABAAB
ABAABABAABAABABAABABAABAABABAAB
ABAABABAABAABABAABABAABAABABAABABAABABAABAABABAABAAB
```

en.wikipedia.org/wiki/L-system

Heighway Dragon



dragon.py

```
import matplotlib.pyplot as plt
from math import sin, cos, radians

axiom = 'FX'
rules = {'X': 'X+YF+', 'Y': '-FX-Y'}

def apply_rules(axiom, rules, repeat):
    for _ in range(repeat):
        axiom = ''.join(rules.get(symbol, symbol) for symbol in axiom)
    return axiom

def walk(commands, position=(0, 0), angle=0, turn=90):
    path = [position]
    for move in commands:
        if move == 'F':
            position = (position[0] + cos(radians(angle)),
                        position[1] + sin(radians(angle)))
            path.append(position)
        elif move == '-': angle -= turn
        elif move == '+': angle += turn
    return path

path = walk(apply_rules(axiom, rules, 13))
plt.plot(*zip(*path), '-')
plt.title('Heighway dragon')
plt.show()
```

Interprete the symbols of the resulting string as a walk where 'F' = draw line forward, and '+' and '-' are turn left and right 90° (X and Y are skipped)

FX+YF++-FX-YF++-FX+YF+--FX-YF++-FX+YF++-FX-YF+--FX+YF+--FX-YF++-FX+YF++-FX-YF++-FX+YF+--FX-YF+--FX+YF++-FX-YF+--FX+YF+--FX-YF++-FX+YF++-FX-YF++-FX+YF+--FX-YF++-FX+YF++-FX-YF+--FX+Y

More space filling curves…

Sierpinski triangle

Axiom F-G-G
F → F-G+F+G-F
G→ GG

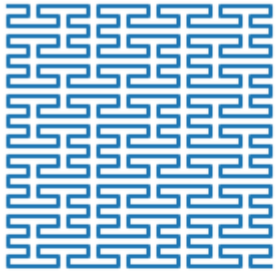
Forward F and G
Turns 120°

Sierpinski arrowhead curve

Axiom A
A → B-A-B
B → A+B+A

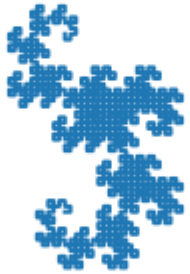
Forward A and B
Turns 60°

Peano curve



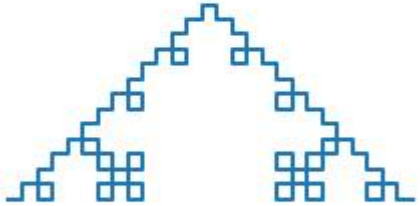
Axiom L
L → LFRFL-F-RFLFR+F+LFRFL
R→ RFLFR+F+LFRFL-F-RFLFR

Heighway dragon



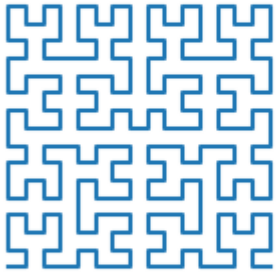
Axiom FX
X → X+YF+
Y → -FX-Y

Koch curve



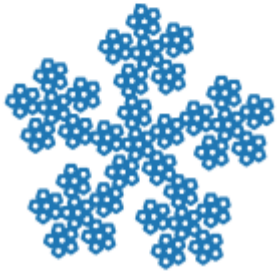
Axiom F
F → F+F-F-F+F

Hilbert curve



Axiom L
L → +RF-LFL-FR+
R → -LF+RFR+FL-

McWorter Pentigree curve



Axiom F-F-F-F-F
F → F-F-F++F+F-F

Turns 72°

Tree

Axiom F
F → F[+FF][-FF]F[-F][+F]F

Turns 36°
[and] return to start point when done

Cesero fractal

Axiom F
F → F+F--F+F

Turns 80°

More space filling curves… (source code)

space-filling-L_systems.py

```
import matplotlib.pyplot as plt
from math import sin, cos, radians

def walk(commands,
         pos=(0, 0),
         forward=frozenset('F'),
         angle=0,
         turn=90):
  paths = [[pos]]
  stack = []
  for move in commands:
    if move in forward:
      pos = (pos[0]+cos(radians(angle)),
             pos[1]+sin(radians(angle)))
      paths[-1].append(pos)
    elif move == '-': angle -= turn
    elif move == '+': angle += turn
    elif move == '[':
      stack.append((pos, angle))
    elif move == ']':
      pos, angle = stack.pop()
      paths.append([pos])
  return paths
```

```
def apply_rules(axiom, rules, repeat=1):
    for _ in range(repeat):
        axiom = ''.join(rules.get(symbol, symbol) for symbol in axiom)
    return axiom

curves = [  # Lindenmayer systems (L-systems)
  ('Sierpinski triangle', 'F-G-G', {'F': 'F-G+F+G-F', 'G': 'GG'}, 5, {'turn': 120, 'forward': {'F','G'}}),
  ('Sierpinski arrowhead curve', 'A', {'A': 'B-A-B', 'B': 'A+B+A'}, 5, {'turn': 60, 'forward': {'A','B'}}),
  ('Peano curve', 'L', {'L': 'LFRFL-F-RFLFR+F+LFRFL', 'R': 'RFLFR+F+LFRFL-F-RFLFR'}, 3, {}),
  ('Heighway dragon','FX', {'X': 'X+YF+', 'Y': '-FX-Y'}, 10, {}),
  ('Koch curve', 'F', {'F': 'F+F-F-F+F'}, 3, {}),
  ('Hilbert curve', 'L', {'L': '+RF-LFL-FR+', 'R': '-LF+RFR+FL-'}, 4, {}),
  ('McWorter Pentigree curve', 'F-F-F-F-F', {'F': 'F-F-F++F+F-F'}, 3, {'turn': 72}),
  ('Tree', 'F', {'F': 'F[+FF][-FF]F[-F][+F]F'}, 3, {'turn': 36}),
  ('Cesero fractal', 'F', {'F': 'F+F--F+F'}, 5, {'turn': 80})
]

for idx, (title, axiom, rules, repeat, walk_arg) in enumerate(curves, start=1):
    paths = walk(apply_rules(axiom, rules, repeat), **walk_arg)
    ax = plt.subplot(3, 3, idx, aspect='equal')
    ax.set_title(title)
    for path in paths:
        plt.plot(*zip(*path), '-')
plt.axis('off')
plt.show()
```