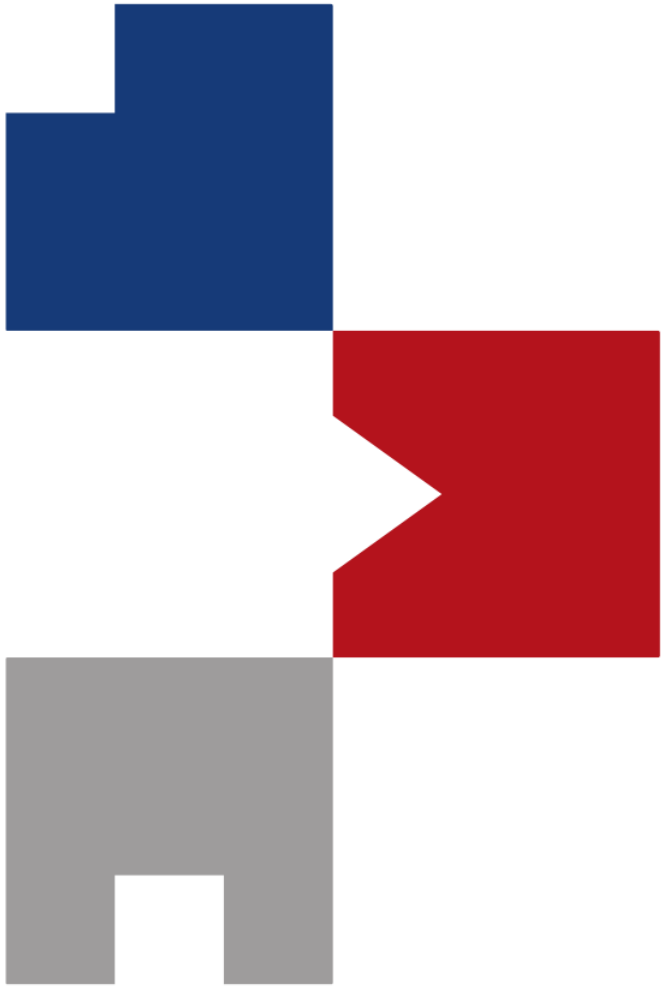
Note) Slides and example codes are available:
https://github.com/mint-lab/prog_meets_math



Python: Standard Library

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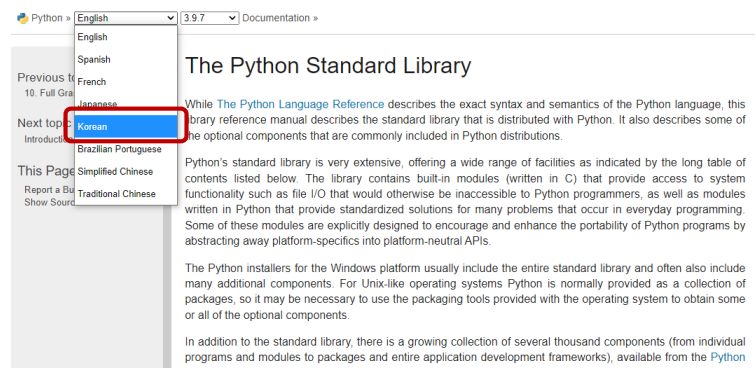
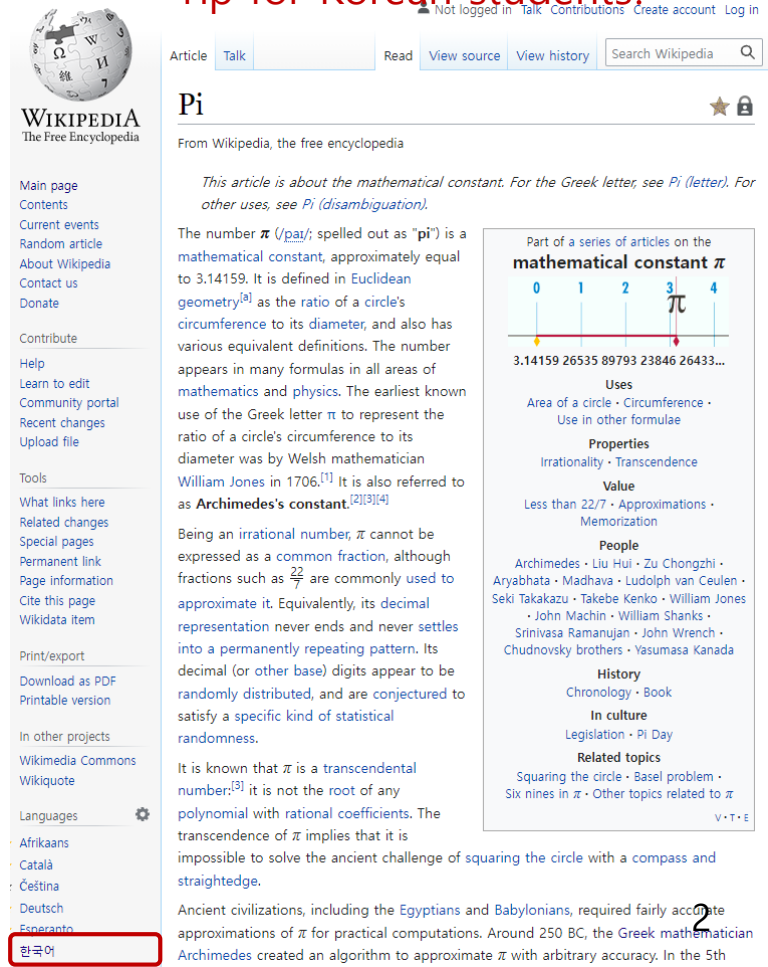
Python: Basic → Intermediate + Standard Library

- Data Types
- Operators
- Flow Control
- Function Definition
- Object-oriented Programming
- File Input and Output
- Exception Handling
- Package Import
- **The Python Standard Library / 파이썬 라이브러리 (Wikidocs)**
  - math, decimal, random
  - time / glob, fnmatch
  - csv, pickle
  - tkinter / turtle

Image: Python Official Documentation, Wikpedia



Tip for Korean students!



My Comments for Better Python Programming

1. Take advantages of Python itself (a.k.a. *Pythonic*)

- e.g. Swap using unpacking

```
temp = a
a = b
b = temp
```

vs.

```
(a, b) = (b, a)
```

- References
  - Code Style, The Hitchhiker's Guide to Python
  - Write More Pythonic Code, Real Python
  - PEP 8 – Style Guide for Python Code, Python

2. Utilize the exiting libraries (a.k.a. *Don't reinvent the wheel*) and master them if they are useful

- Problem #1) Too many libraries
  - Search your keywords in **Google**/Github (with *python*), PyPI, and …
- Problem #2) A few documents and examples
  - Select a popular one (if possible)
  - Search your problem in **Google** (or analyze the source codes)

`math`: Mathematical Functions

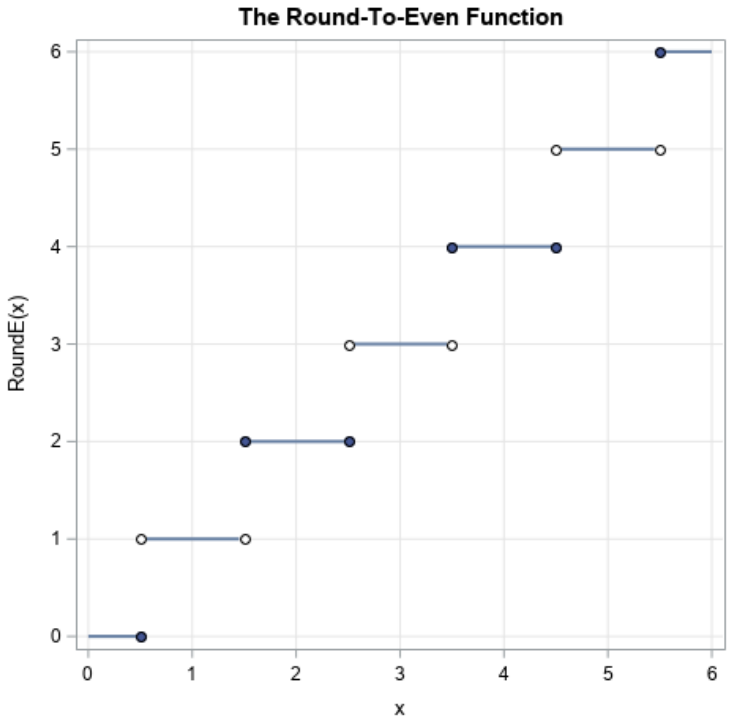
- `math` provides various and useful mathematical functions similar to the C standard library.
- API examples
  - Constants: `pi` (3.14..., the ratio of a circle's circumference to its diameter; 원주율), `e` (2.718..., the base for natural logarithm; 자연상수), `inf` (a floating-point positive infinity), `nan` (a floating-point not-a-number; NaN)
  - `sqrt(x)`: Return the square root of `x`
  - `log(x[, base])`, `log2(x)`, `log10(x)`: Return the natural logarithm, base-2 logarithm, and base-10 logarithm of `x`
  - `ceil(x)`: Return the smallest integer greater than or equal to `x`
  - `prod(iterable, *, start=1)`: Calculate the product of all the elements in the input `iterable`
  - `sin(x)`, `cos(x)`, `tan(x)`, ..., `atan(x)`, `atan2(y, x)`: Trigonometric functions
  - `degrees(x)`, `radians(x)`: Convert angle `x` from radians to degrees (or vice versa)
  - `isinf(x)`, `isnan(x)`, `isfinite(x)`: Check whether `x` is an infinity or a NaN or finite (neither an infinity nor a NaN)
- Usage example

```
import math
factorial_prod = lambda n: math.prod(range(1, n + 1))
print(factorial_prod(10)) # 3628800
```

decimal: Decimal Fixed-point and Floating-point Arithmetic

- decimal provides fast correctly-rounded decimal floating-point arithmetic.
- API examples
  - `Decimal`: A class for a decimal floating-point value
  - `Decimal.quantize(exp, rounding=None, context=None)`: Return a rounded value with precision of exp
- Usage example: Rounding

```
# Using the default built-in function
print(round(3.5)) # 4
print(round(4.5)) # 4 (not 5)

# Using the decimal module
import decimal
print(decimal.getcontext()) # rounding=decimal.ROUND_HALF_EVEN
print(decimal.Decimal(3.5).quantize(1, decimal.ROUND_HALF_UP)) #
print(decimal.Decimal(4.5).quantize(1, decimal.ROUND_HALF_UP)) #

# Using a simple hand-made function
round2 = lambda x: int(x + 0.5)
print(round2(3.5)) # 4
print(round2(4.5)) # 5
```



Why? To avoid systemic bias

e.g. `round(1.5) + round(2.5) + round(3.5) + round(4.5)`

Image: SAS blogs

random: Pseudo-random Number Generators

- random provides pseudo-random generators for various probability distributions.
- API examples
  - `random()`: Return the next random floating-point number in the range [0.0, 1.0)
  - `randint(a, b)`: Return a random integer `N` such that `a <= N <= b`
  - `uniform(a, b)`: Return a random floating-point number `N` such that `a <= N <= b`
  - `gauss(mu, sigma)`, `normalvariate(mu, sigma)`: Return a random floating-point number under Gaussian distribution whose mean is `mu` and standard deviation is `sigma`
  - `seed(a=None, version=2)`: Initialize the random number generator (`a=None`; the current system time is used)
- Usage example: Uniform vs. Gaussian

```
import random
round2 = lambda x: int(x + 0.5)
print([round2(random.uniform(0, 10)) for i in range(10)]) # [2, 7, 6, 0, 3, 5, 3, 5, 7, 1]
print([round2(random.gauss(5, 1)) for i in range(10)])    # [5, 6, 6, 3, 5, 5, 5, 5, 7, 6]
```

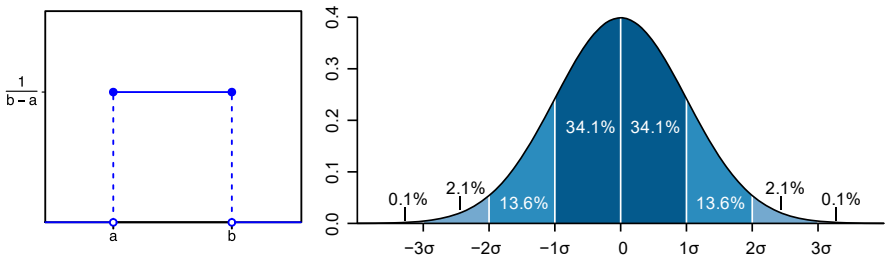


Image: Wikipedia

time: Time Access and Conversions

- time provides various time-related functions. (For related functionality, see also datetime and calendar)
- API examples
  - `time()`: Return the current time in seconds since the epoch (January 1st, 1970, 00:00:00 (UTC) for Unix)
  - `process_time()`, `thread_time()`: Return the sum of CPU time of the current process and thread (except `sleep`)
  - `gmtime([secs])`, `localtime([secs])`: Return the time as `time.struct_time` in UTC and your local time zone
  - `asctime([tm_struct])`, `ctime([secs])`: Return the time as a short string
  - `sleep(secs)`: Suspend execution of the current thread for the given seconds
- Usage example

```
import time
print(time.time())            # 1632946803.815631
print(time.process_time())    # 4.59375
print(time.thread_time())     # 3.890625
print(time.localtime())       # time.struct_time(..., tm_mday=30, tm_hour=5, ...)
print(time.gmtime())          # time.struct_time(..., tm_mday=29, tm_hour=20, ...)
print(time.ctime())           # Thu Sep 30 05:20:03 2021

start = time.time()
time.sleep(2)
elapse = time.time() - start # 2.0132129000012355
print(elapse)
```

glob: Unix-style Pathname Pattern Expansion

- glob finds all files and directories matched with a specified pattern used by the Unix shell.
  - **Wildcards** [Wikipedia]

Wildcard	Description	Example	Matches	Does not match
*	**Everything** including none	Law*	Law, Laws, Lawyer	GrokLaw, La, aw
		Law	Law, GrokLaw, Lawyer	La, aw
?	**Any single** character	?at	Cat, cat, Bat, bat	at
[abc]	**One** character given **in the bracket**	[CB]at	Cat, Bat	cat, bat, CBat
[a-z]	**One** character **within the range**	Letter[0-9]	Letter0, Letter1, … , Letter9	Letters, Letter, Letter10

- API examples
  - `glob(pathname, *, recursive=False)`: Return a list of names of files and directories that match `pathnames`
- Usage example

```
# Please be aware where your working directory is (use 'pwd' in IPython console).
import glob                                # from glob import glob
glob.glob('*.py')                          # glob('*.py')
glob.glob('data/class_score_??.csv') # glob('data/class_score_??.csv')
```

fnmatch: Unix-style String Pattern Matching

- fnmatch finds all strings matched with a specified pattern according to the rules used by the Unix shell.
- API examples
  - `fnmatch(text, pattern)`: Test whether `text` matches the `pattern` (True or False; **case-insensitive**)
  - `fnmatchcase(text, pattern)`: Similar to `fnmatch()` but **case-sensitive**
  - `filter(iterable, pattern)`: Return a list of elements in `iterable` which satisfies `pattern`
- Usage example

```
import fnmatch
profs = [ 'My name is Choi and my E-mail is sunglok@seoultech.ac.kr.',
          'My name is Kim and my e-mail address is jindae.kim@seoultech.ac.kr.']

# For a single string
print([fnmatch.fnmatch(prof, 'e-mail') for prof in profs])          # [False, False]
print([fnmatch.fnmatch(prof, '*e-mail*') for prof in profs])        # [True, True]
print([fnmatch.fnmatchcase(prof, '*e-mail*') for prof in profs])    # [False, True]
print([fnmatch.fnmatchcase(prof, '*[Ee]-mail*') for prof in profs]) # [True, True]

# For a list of strings
print(fnmatch.filter(profs, '*e-mail*')) # ['My ... Choi ...', 'My ... Kim ...']
print(fnmatch.filter(profs, '*Ch?i*'))   # ['My ... Choi ...']
```

csv: CSV File Reading and Writing

- csv contains classes to read and write tabular data in comma-separated values (CSV) format.
- API examples
  - `reader(file_obj, dialect='excel', **fmtparams)`: Return a reader object which can access lines in `file_obj`
  - `writer(file_obj, dialect='excel', **fmtparams)`: Return a writer object which can convert user data into comma-separated string on `file_obj`
- Usage example: Read all CSV files

```
# Please be aware where your working directory is (use 'pwd' in IPython console).
import glob, csv

files = glob.glob('data/class_score_??.csv')
all_data = []
for file in files:
    with open(file, 'r') as f:      # Construct a file object
        csv_reader = csv.reader(f) # Construct a CSV reader object
        data = []
        for line in csv_reader:     # e.g. line = ['113', '86']
            if line and not line[0].strip().startswith('#'): # If 'line' is valid and not a header
                data.append([int(val) for val in line])      # Append 'line' to 'data' as numbers
        all_data = all_data + data                           # Merge 'data' to 'all_data'
```

pickle: Python Object Serialization

- pickle provides binary protocols for serializing and de-serializing a Python object.
  - ~ You can save and load a Python object (in binary) without worry about its file format.
- API examples
  - `dump(obj, file_obj, …)`: Write the given Python object `obj` into `file_obj`
  - `load(file_obj, …)`: Read `file_obj` and return its Python object
- Usage example: Writing data to a file

```
# Please run the previous example, 'Read all CSV files'.
import pickle
with open('class_score_all.pickle', 'wb') as f:
    pickle.dump((files, all_data), f)
```

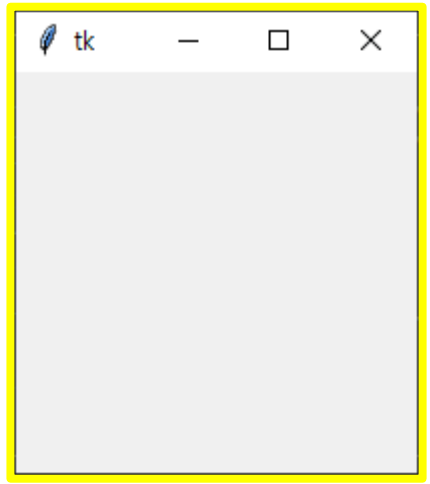
- Usage example: Loading data from the file

```
# Please be sure that 'class_score_all.pickle' was generated.
import pickle
with open('class_score_all.pickle', 'rb') as f:
    _, data = pickle.load(f)
    print(data)
```

tkinter: Python Interface to Tcl/Tk GUI Toolkit

- tkinter is the standard Python interface to the Tcl/Tk GUI toolkit.
- API examples
  - David Amos, Python GUI Programming with Tkinter, Real Python
  - 박응용, tkinter – 편리한 GUI 툴킷, 파이썬 라이브러리, Wikidocs
- Usage example: Hello World

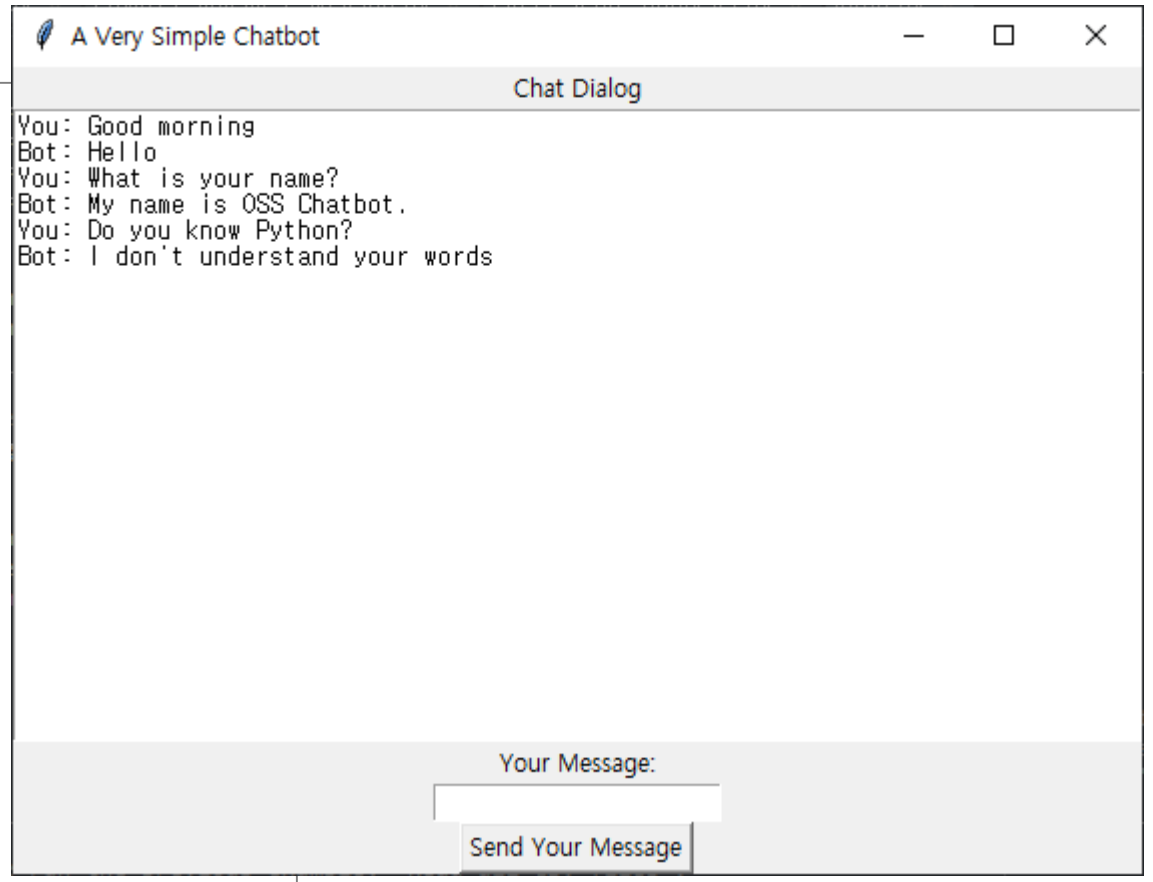
```
import tkinter as tk

root = tk.Tk()
label = tk.Label(root, text='Hello, World!')
label.pack()

root.mainloop()
```



tkinter: Python Interface to Tcl/Tk GUI Toolkit

- Usage example: A very simple chatbot

```
import tkinter as tk
from fnmatch import fnmatch

# Generate reply to the given message
def reply_msg(msg):
    if fnmatch(msg, '*hello*') or fnmatch(msg, '*good morning*'):
        return 'Hello'
    elif fnmatch(msg, '*what*you*name*'):
        return 'My name is OSS Chatbot.'
    return "I don't understand your words."

# Handle events from 'button_send'
def handle_button_send():
    text_dialog.insert('end', 'You: ' + entry_msg.get() + '\n')
    text_dialog.insert('end', 'Bot: ' + reply_msg(entry_msg.get()) + '\n')
    entry_msg.delete(0, tk.END) # Clear 'entry_msg' after reply

# Add widgets to GUI
root = tk.Tk()
root.title('A Very Simple Chatbot')
label = tk.Label(root, text='Chat Dialog')
label.pack()
text_dialog = tk.Text(root)
text_dialog.pack()
label = tk.Label(root, text='Your Message:')
label.pack()
entry_msg = tk.Entry(root)
entry_msg.pack()
button_send = tk.Button(root, text='Send Your Message', command=handle_button_send)
button_send.pack()

root.mainloop()
```



tkinter: Python Interface to Tcl/Tk GUI Toolkit

- Usage example: A very simple chatbot after refactoring (`simple_chatbot.py`)

```python
import tkinter as tk
from fnmatch import fnmatch

class ChatBot:
    def __init__(self):
        self.talk_table = [
            ('*hello*',         'Hello'),
            ('*good morning*',  'Hello'),
            ('*what*you*name*', 'My name is OSS Chatbot.'),
        ]
        self.talk_unknown = "I don't understand your words."

    def reply(self, msg):
        for pattern, response in self.talk_table:
            if fnmatch(msg, pattern):
                return response
        return self.talk_unknown
```

2) Separate the data (`talk_*`) and algorithm (`reply`)

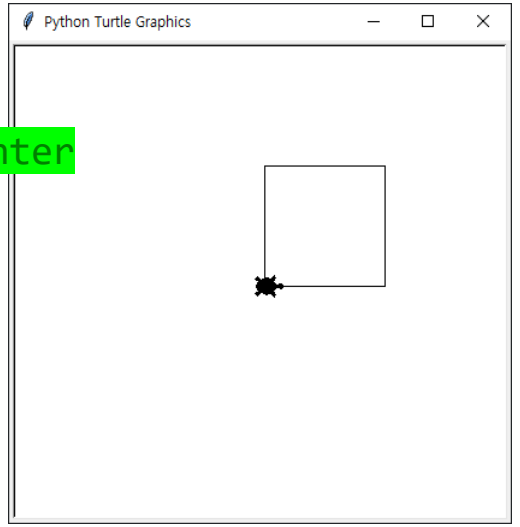
```python
class SimpleChatBotGUI:
    def __init__(self, chatbot, master):
        self.chatbot = chatbot
        self.master = master
        self.master.title('A Very Simple Chatbot')
        self.label = tk.Label(master, text='Chat Dialog')
        self.label.pack()
        self.text_dialog = tk.Text(master)
        self.text_dialog.pack()
        self.label = tk.Label(master, text='Your Message:')
        self.label.pack()
        self.entry_msg = tk.Entry(master)
        self.entry_msg.pack()
        self.button_send = tk.Button(master, text='Send Your Message',
                                     command=self.handle_button)
        self.button_send.pack()

    def handle_button(self):
        msg = self.entry_msg.get()
        self.text_dialog.insert('end', 'You: ' + msg + '\n')
        self.text_dialog.insert('end', 'Bot: ' + self.chatbot.reply(msg) + '\n')
        self.entry_msg.delete(0, tk.END) # Clear 'entry_msg' after reply

if __name__ == '__main__':
    chatbot = ChatBot()
    root = tk.Tk()
    app = SimpleChatBotGUI(chatbot, root)
    root.mainloop()
```

1) Separate the model (**`ChatBot`**) and its view (**`SimpleChatBotGUI`**) [Wikipedia]

`turtle`: Turtle Graphics for Programming Education

- Turtle graphics was a vector drawing tool for introducing programming to kids.
  - It was a part of the original Logo programming language, which has been re-implemented in Python with `tkinter`.
- API examples
  - **`Turtle`** class
    - Motion: `forward()`, `backward()`, `right()`, `left()`, `goto()`/`setpos()`, `setx()`, `sety()`, `setheading()`, …
    - Pen: `penup()`, `pendown()`, `pensize()`, `pencolor()`, …
    - State: `pos()`, `heading()`, `distance()`, … / `isdown()`, …
  - **`TurtleScreen`/`Screen`** class
    - Event: `mainloop()`, `onkeypress()`, …
- Usage example: Drawing a rectangle

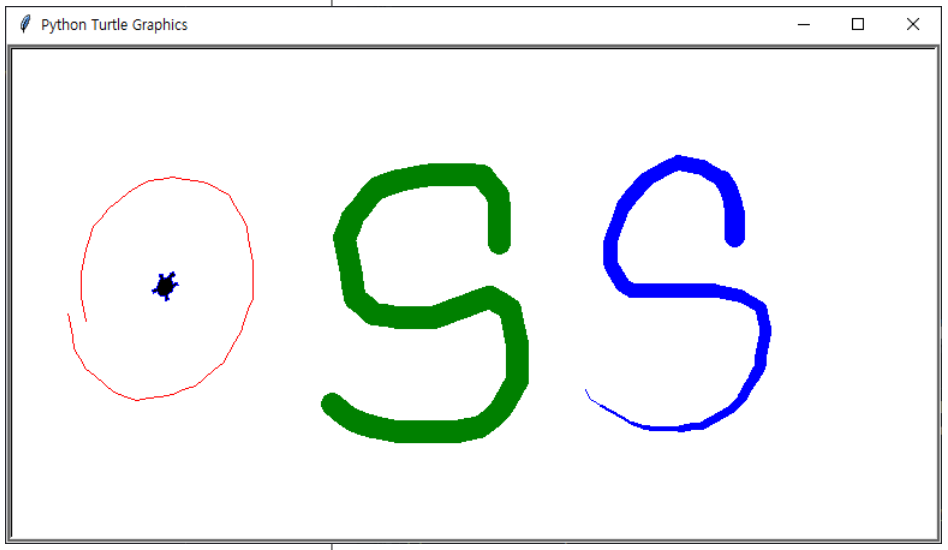
```
# If you use Spyder, please change your configuration as follows:
# - Menu > Tools > Preference > IPython console > Graphics > Graphics backend: Tkinter
# After your practice, please restore the configuration to 'Automatic' again.
import turtle

turtle.shape('turtle')
for i in range(4):
    turtle.forward(100) # Unit: Pixel
    turtle.left(90)     # Unit: Degree
```



turtle: Turtle Graphics for Programming Education

- Usage example: Turtle painter (1/2)

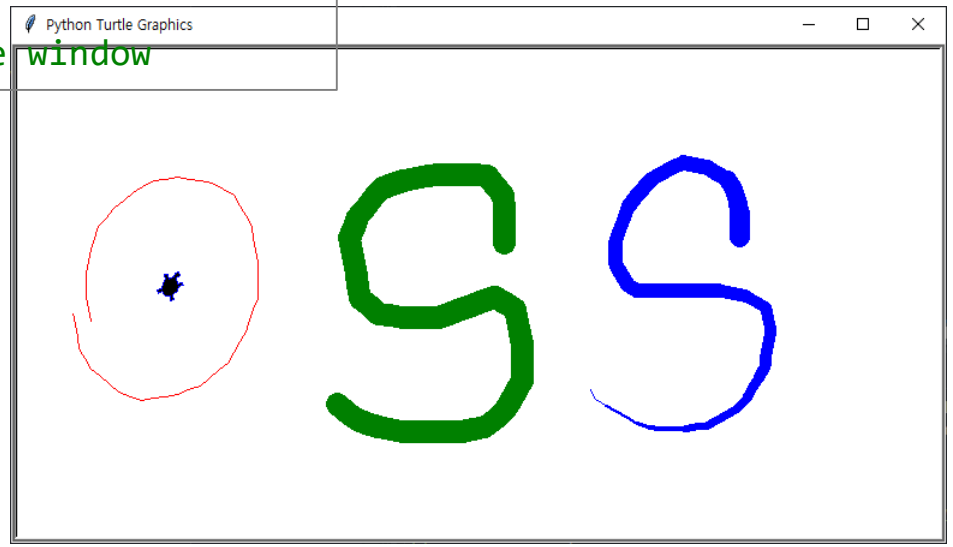
```
import turtle

pen_pallate = ['black', 'red', 'green', 'blue', 'cyan', 'magenta', 'yellow']
pen_color = 0
pen_width = 3
pen_delta = 1
step_move = 10
step_turn = 10

def shift_pen_color():
    global pen_color
    pen_color = (pen_color + 1) % len(pen_pallate)
    turtle.pencolor(pen_pallate[pen_color])

def change_pen_width(delta):
    global pen_width
    pen_width += delta
    if pen_width < 1:
        pen_width = 1
    turtle.pensize(pen_width)

# Initialize the turtle
turtle.shape('turtle')
turtle.pencolor(pen_pallate[pen_color])
turtle.pensize(pen_width)
```



turtle: Turtle Graphics for Programming Education

- Usage example: Turtle painter (2/2)

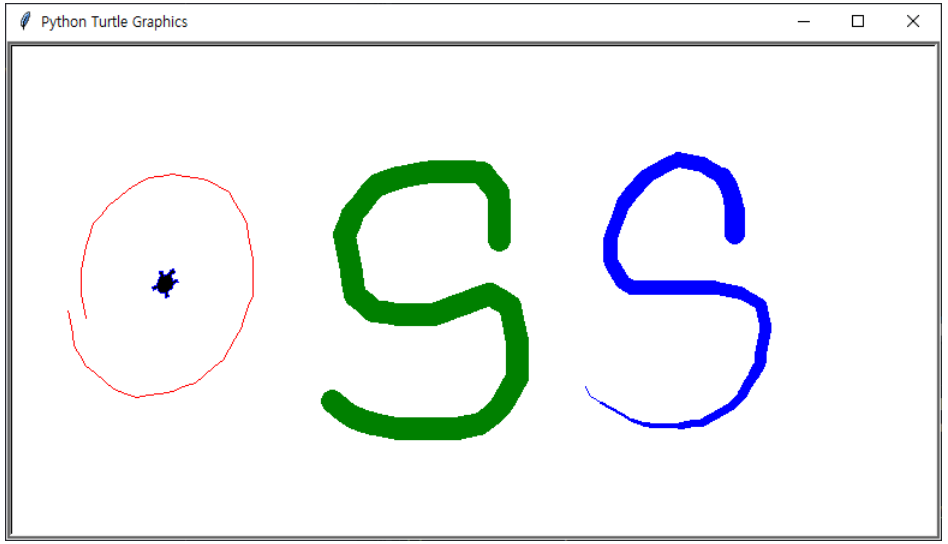
```
# Register event handlers
turtle.onkeypress(shift_pen_color, 'c')
turtle.onkeypress(lambda: turtle.forward(step_move), 'Up')
turtle.onkeypress(lambda: turtle.backward(step_move), 'Down')
turtle.onkeypress(lambda: turtle.left(step_turn), 'Left')
turtle.onkeypress(lambda: turtle.right(step_turn), 'Right')
turtle.onkeypress(lambda: turtle.clear(), 'Escape')
turtle.onkeypress(lambda: turtle.pen(pendown=not turtle.isdown()), ' ')
turtle.onkeypress(lambda: change_pen_width(+pen_delta), 'm')
turtle.onkeypress(lambda: change_pen_width(-pen_delta), 'n')
turtle.listen()

#turtle.mainloop() # It is necessary out of Spyder, not to close the window
```



```python
# This example is not working in Spyder directly (F5 or Run)
# Please type '!python turtle_painter.py' on IPython console in your Spyder.
import turtle

class TurtlePainter(turtle.RawTurtle):
    def __init__(self, canvas):
        super().__init__(canvas)
        self.pen_pallate = ['black', 'red', 'green', 'blue', 'cyan', 'magenta', 'yellow']
        self.pen_color = 0
        self.pen_width = 3
        self.pen_delta = 1
        self.step_move = 10
        self.step_turn = 10

        # Initialize the turtle
        self.shape('turtle')
        self.pencolor(self.pen_pallate[self.pen_color])
        self.pensize(self.pen_width)

        # Register event handlers
        canvas.onkeypress(self.shift_pen_color, 'c')
        canvas.onkeypress(lambda: self.forward(self.step_move), 'Up')
        canvas.onkeypress(lambda: self.backward(self.step_move), 'Down')
        canvas.onkeypress(lambda: self.left(self.step_turn), 'Left')
        canvas.onkeypress(lambda: self.right(self.step_turn), 'Right')
        canvas.onkeypress(lambda: self.clear(), 'Escape')
        canvas.onkeypress(lambda: self.pen(pendown=not self.isdown()), ' ')
        canvas.onkeypress(lambda: self.change_pen_width(+self.pen_delta), 'm')
        canvas.onkeypress(lambda: self.change_pen_width(-self.pen_delta), 'n')
        canvas.listen()

    def shift_pen_color(self):
        self.pen_color = (self.pen_color + 1) % len(self.pen_pallate)
        self.pencolor(self.pen_pallate[self.pen_color])

    def change_pen_width(self, delta):
        self.pen_width = max(self.pen_width + delta, 1)
        self.pensize(self.pen_width)
```

Usage example: Turtle painter after refactoring (turtle_painter.py)

```python
if __name__ == '__main__':
    canvas = turtle.Screen()
    painter = TurtlePainter(canvas)
    # You can add another turtles by additional instantiation.
    # another = turtle.Turtle('turtle')
    # another.penup()
    # another.goto(100, 100)
    canvas.mainloop()
```



Beyond the Python Standard Library

- How to install a pre-built Python library (usually available in PyPI)
  - Shell/Anaconda Prompt: `pip install package_name`
  - IPython console (in Spyder): `!pip install package_name`
- Example: Face detection using OpenCV (`face_detection.py`)
  - Install OpenCV: `pip install opencv-python`
  - Download a pre-trained model file, `haarcascade_frontalface_default.xml`
  - Prepare your test image or camera

Beyond the Python Standard Library

- Example: Face detection using OpenCV (`face_detection.py`)
  - Install OpenCV: `pip install opencv-python`
  - Download a pre-trained model file, `haarcascade_frontalface_default.xml`
  - Prepare your test image or camera

```python
import cv2 as cv

# Load a face detector
face_detector = cv.CascadeClassifier('data/haarcascade_frontalface_default.xml')

# Prepare an image in gray scale
img = cv.imread('data/poster.jpg')
gray = cv.cvtColor(img, cv.COLOR_BGR2GRAY)

# Detect faces
faces = face_detector.detectMultiScale(gray)

# Visualize results
for (x, y, w, h) in faces:
    cv.rectangle(img, (x, y), (x+w, y+h), (0, 0, 255), 2)
cv.imshow('Face Detection using OpenCV', img)
cv.waitKey()
cv.destroyAllWindows()
```

tqdm: Progress Visualization in Console

- tqdm visualizes progress of iterations in console.
  - Note) The name, tqdm, came from *taqadum* (progress in Arabic).
- Simple visualization

```
n = 10000
for i in range(n):
    pass                                # Do something
    print(f'{i} / {n} ({100*i//n}%)') # Print progress

# ...
# 9998 / 10000 (100%)
# 9999 / 10000 (100%)
```

- Usage example

```
from tqdm import tqdm
n = 10000
for i in tqdm(range(n)):
    pass # Do something

# 76%|████████████████████████████████          | 7568/10000 [00:33<00:10, 229.00it/s]
```

Summary

- `math`: Mathematical Functions
- `decimal`: Decimal Fixed-point and Floating-point Arithmetic
- `random`: Pseudo-random Number Generators
- `time`: Time Access and Conversions
- `glob`: Unix-style Pathname Pattern Expansion
- `fnmatch`: Unix-style String Pattern Matching
- `csv`: CSV File Reading and Writing
- `pickle`: Python Object Serialization
- `tkinter`: Python Interface to Tcl/Tk GUI Toolkit
  - **Refactoring**
- `turtle`: Turtle Graphics for Programming Education
  - **Refactoring**
- Beyond the Python Standard Library
  - `pip install package_name`
- `tqdm`: Progress Visualization in Console