

ADVANCED CHEAT SHEET

The goal of this part is to give common snippets including built-in and 3rd party modules usages.

3.1 Regular Expression

Table of Contents

- *Regular Expression*
 - *Compare HTML tags*
 - *`re.findall()` match string*
 - *Group Comparison*
 - *Non capturing group*
 - *Back Reference*
 - *Named Grouping (`?P<name>`)*
 - *Substitute String*
 - *Look around*
 - *Match common username or password*
 - *Match hex color value*
 - *Match email*
 - *Match URL*
 - *Match IP address*
 - *Match Mac address*
 - *Lexer*

3.1.1 Compare HTML tags

tag type	format	example
all tag	<[>]+>	 , <a>
open tag	<[>][>]*>	<a>, <table>
close tag	</[>]+>	</p>,
self close	<[>]+/>	

```
# open tag
>>> re.search('<[>][>]*>', '<table>') != None
True
>>> re.search('<[>][>]*>', '<a href="#label">') != None
True
>>> re.search('<[>][>]*>', '') != None
True
>>> re.search('<[>][>]*>', '</table>') != None
False

# close tag
>>> re.search('</[>]+>', '</table>') != None
True

# self close
>>> re.search('<[>]+/>', '<br />') != None
True
```

3.1.2 re.findall() match string

```
# split all string
>>> source = "Hello World Ker HAHA"
>>> re.findall('[\w]+', source)
['Hello', 'World', 'Ker', 'HAHA']

# parsing python.org website
>>> import urllib
>>> import re
>>> s = urllib.urlopen('https://www.python.org')
>>> html = s.read()
>>> s.close()
>>> print("open tags")
open tags
>>> re.findall('<[>][>]*>', html)[0:2]
['<!doctype html>', '<!--[if lt IE 7]>']
>>> print("close tags")
close tags
>>> re.findall('</[>]+>', html)[0:2]
['</script>', '</title>']
>>> print("self-closing tags")
self-closing tags
>>> re.findall('<[>]+/>', html)[0:2]
```

(continues on next page)

(continued from previous page)

[]

3.1.3 Group Comparison

```
# (...) group a regular expression
>>> m = re.search(r'(\d{4})-(\d{2})-(\d{2})', '2016-01-01')
>>> m
<_sre.SRE_Match object; span=(0, 10), match='2016-01-01'>
>>> m.groups()
('2016', '01', '01')
>>> m.group()
'2016-01-01'
>>> m.group(1)
'2016'
>>> m.group(2)
'01'
>>> m.group(3)
'01'

# Nesting groups
>>> m = re.search(r'(((\d{4})-\d{2})-\d{2})', '2016-01-01')
>>> m.groups()
('2016-01-01', '2016-01', '2016')
>>> m.group()
'2016-01-01'
>>> m.group(1)
'2016-01-01'
>>> m.group(2)
'2016-01'
>>> m.group(3)
'2016'
```

3.1.4 Non capturing group

```
# non capturing group
>>> url = 'http://stackoverflow.com/'
>>> m = re.search('(?:http|ftp):\/\/([^\r\n]+)(\/[^\r\n]*)?', url)
>>> m.groups()
('stackoverflow.com', '/')

# capturing group
>>> m = re.search('(http|ftp):\/\/([^\r\n]+)(\/[^\r\n]*)?', url)
>>> m.groups()
('http', 'stackoverflow.com', '/')
```

3.1.5 Back Reference

```
# compare 'aa', 'bb'
>>> re.search(r'([a-z])\1$', 'aa') != None
True
>>> re.search(r'([a-z])\1$', 'bb') != None
True
>>> re.search(r'([a-z])\1$', 'ab') != None
False

# compare open tag and close tag
>>> pattern = r'<([^>]+)>[\s\S]*?</\1>'
>>> re.search(pattern, '<bold> test </bold>') != None
True
>>> re.search(pattern, '<h1> test </h1>') != None
True
>>> re.search(pattern, '<bold> test </h1>') != None
False
```

3.1.6 Named Grouping (?P<name>)

```
# group reference ``(?P<name>...)``
>>> pattern = '(?P<year>\d{4})-(?P<month>\d{2})-(?P<day>\d{2})'
>>> m = re.search(pattern, '2016-01-01')
>>> m.group('year')
'2016'
>>> m.group('month')
'01'
>>> m.group('day')
'01'

# back reference ``(?P=name)``
>>> re.search('^(?P<char>[a-z])(?P=char)', 'aa')
<_sre.SRE_Match object at 0x10ae0f288>
```

3.1.7 Substitute String

```
# basic substitute
>>> res = "1a2b3c"
>>> re.sub(r'[a-z]', ' ', res)
'1 2 3 '

# substitute with group reference
>>> date = r'2016-01-01'
>>> re.sub(r'(\d{4})-(\d{2})-(\d{2})', r'\2/\3/\1/', date)
'01/01/2016/'

# camelcase to underscore
>>> def convert(s):
...     res = re.sub(r'([A-Z][a-z]+)', r'\1_\2', s)
```

(continues on next page)

(continued from previous page)

```

...     return re.sub(r'([a-z])([A-Z])',r'\1_\2', res).lower()
...
>>> convert('CamelCase')
'camel_case'
>>> convert('CamelCamelCase')
'camel_camel_case'
>>> convert('SimpleHTTPServer')
'simple_http_server'

```

3.1.8 Look around

notation	compare direction
(?=...)	left to right
(?!...)	left to right
(?<=...)	right to left
(?!<...)	right to left

```

# basic
>>> re.sub('(?=\d{3})', ' ', '12345')
' 1 2 345'
>>> re.sub('(?!\d{3})', ' ', '12345')
'123 4 5 '
>>> re.sub('(?<=\d{3})', ' ', '12345')
'123 4 5 '
>>> re.sub('(?!<\d{3})', ' ', '12345')
' 1 2 345'

```

3.1.9 Match common username or password

```

>>> re.match('^[a-zA-Z0-9-]{3,16}$', 'Foo') is not None
True
>>> re.match('^[w|[-_]{3,16}$', 'Foo') is not None
True

```

3.1.10 Match hex color value

```

>>> re.match('^#?([a-f0-9]{6}|[a-f0-9]{3})$', '#ffffff')
<_sre.SRE_Match object at 0x10886f6c0>
>>> re.match('^#?([a-f0-9]{6}|[a-f0-9]{3})$', '#fffffh')
<_sre.SRE_Match object at 0x10886f288>

```

3.1.11 Match email

```
>>> re.match('^([a-z0-9_\.-]+)@([\da-z\.-]+\.[a-z\.]{2,6})$',
...         'hello.world@example.com')
<_sre.SRE_Match object at 0x1087a4d40>

# or

>>> exp = re.compile(r'''^([a-zA-Z0-9._-]+@
...                 [a-zA-Z0-9.-]+
...                 \.[a-zA-Z]{2,4})*$''', re.X)
>>> exp.match('hello.world@example.hello.com')
<_sre.SRE_Match object at 0x1083efd50>
>>> exp.match('hello%world@example.hello.com')
<_sre.SRE_Match object at 0x1083efeb8>
```

3.1.12 Match URL

```
>>> exp = re.compile(r'''^(https?:\/\/)? # match http or https
...                 ([\da-z\.-]+)       # match domain
...                 \.[a-z\.]{2,6})     # match domain
...                 ([\/\w \.-]*)\/?$   # match api or file
...                 ''', re.X)
>>>
>>> exp.match('www.google.com')
<_sre.SRE_Match object at 0x10f01ddf8>
>>> exp.match('http://www.example')
<_sre.SRE_Match object at 0x10f01dd50>
>>> exp.match('http://www.example/file.html')
<_sre.SRE_Match object at 0x10f01ddf8>
>>> exp.match('http://www.example/file!.html')
```

3.1.13 Match IP address

notation	description
(?:...)	Don't capture group
25[0-5]	Match 251-255 pattern
2[0-4][0-9]	Match 200-249 pattern
[1]?[0-9][0-9]	Match 0-199 pattern

```
>>> exp = re.compile(r'''^(?:25[0-5]
...                 |2[0-4][0-9]
...                 |1?[0-9][0-9]?)\.){3}
...                 (?:25[0-5]
...                 |2[0-4][0-9]
...                 |1?[0-9][0-9]?)$''', re.X)
>>> exp.match('192.168.1.1')
<_sre.SRE_Match object at 0x108f47ac0>
```

(continues on next page)

(continued from previous page)

```
>>> exp.match('255.255.255.0')
<_sre.SRE_Match object at 0x108f47b28>
>>> exp.match('172.17.0.5')
<_sre.SRE_Match object at 0x108f47ac0>
>>> exp.match('256.0.0.0') is None
True
```

3.1.14 Match Mac address

```
>>> import random
>>> mac = [random.randint(0x00, 0x7f),
...        random.randint(0x00, 0x7f),
...        random.randint(0x00, 0x7f),
...        random.randint(0x00, 0x7f),
...        random.randint(0x00, 0x7f),
...        random.randint(0x00, 0x7f)]
>>> mac = ':'.join(map(lambda x: "%02x" % x, mac))
>>> mac
'3c:38:51:05:03:1e'
>>> exp = re.compile(r'''[0-9a-f]{2}(:)
...                  [0-9a-f]{2}
...                  (\1[0-9a-f]{2}){4}$''', re.X)
>>> exp.match(mac) is not None
True
```

3.1.15 Lexer

```
>>> import re
>>> from collections import namedtuple
>>> tokens = [r'(?P<NUMBER>\d+)',
...           r'(?P<PLUS>\+)',
...           r'(?P<MINUS>-)',
...           r'(?P<TIMES>\*)',
...           r'(?P<DIVIDE>/)',
...           r'(?P<WS>\s+)']
>>> lex = re.compile('|'.join(tokens))
>>> Token = namedtuple('Token', ['type', 'value'])
>>> def tokenize(text):
...     scan = lex.scanner(text)
...     return (Token(m.lastgroup, m.group())
...             for m in iter(scan.match, None) if m.lastgroup != 'WS')
>>> for _t in tokenize('9 + 5 * 2 - 7'):
...     print(_t)
...
Token(type='NUMBER', value='9')
Token(type='PLUS', value='+')
Token(type='NUMBER', value='5')
Token(type='TIMES', value='*')
```

(continues on next page)

(continued from previous page)

```
Token(type='NUMBER', value='2')
Token(type='MINUS', value='-')
Token(type='NUMBER', value='7')
```

3.2 Socket

Socket programming is inevitable for most programmers even though Python provides much high-level networking interface such as `httplib`, `urllib`, `imaplib`, `telnetlib` and so on. Some Unix-Like system's interfaces were called through socket interface, e.g., Netlink, Kernel cryptography. To temper a pain to read long-winded documents or source code, this cheat sheet tries to collect some common or uncommon snippets which are related to low-level socket programming.

Table of Contents

- *Socket*
 - *Get Hostname*
 - *Get address family and socket address from string*
 - *Transform Host & Network Endian*
 - *IP dotted-quad string & byte format convert*
 - *Mac address & byte format convert*
 - *Simple TCP Echo Server*
 - *Simple TCP Echo Server through IPv6*
 - *Disable IPv6 Only*
 - *Simple TCP Echo Server Via SocketServer*
 - *Simple TLS/SSL TCP Echo Server*
 - *Set ciphers on TLS/SSL TCP Echo Server*
 - *Simple UDP Echo Server*
 - *Simple UDP Echo Server Via SocketServer*
 - *Simple UDP client - Sender*
 - *Broadcast UDP Packets*
 - *Simple UNIX Domain Socket*
 - *Simple duplex processes communication*
 - *Simple Asynchronous TCP Server - Thread*
 - *Simple Asynchronous TCP Server - select*
 - *Simple Asynchronous TCP Server - poll*
 - *Simple Asynchronous TCP Server - epoll*
 - *Simple Asynchronous TCP Server - kqueue*
 - *High-Level API - selectors*

- *Simple Non-blocking TLS/SSL socket via selectors*
- *“socketpair” - Similar to PIPE*
- *Using sendfile to copy*
- *Sending a file through sendfile*
- *Linux kernel Crypto API - AF_ALG*
- *AES-CBC encrypt/decrypt via AF_ALG*
- *AES-GCM encrypt/decrypt via AF_ALG*
- *AES-GCM encrypt/decrypt file with sendfile*
- *Compare the performance of AF_ALG to cryptography*
- *Sniffer IP packets*
- *Sniffer TCP packet*
- *Sniffer ARP packet*

3.2.1 Get Hostname

```
>>> import socket
>>> socket.gethostname()
'MacBookPro-4380.local'
>>> hostname = socket.gethostname()
>>> socket.gethostbyname(hostname)
'172.20.10.4'
>>> socket.gethostbyname('localhost')
'127.0.0.1'
```

3.2.2 Get address family and socket address from string

```
import socket
import sys

try:
    for res in socket.getaddrinfo(sys.argv[1], None,
                                   proto=socket.IPPROTO_TCP):
        family = res[0]
        sockaddr = res[4]
        print(family, sockaddr)
except socket.gaierror:
    print("Invalid")
```

Output:

```
$ gai.py 192.0.2.244
AddressFamily.AF_INET ('192.0.2.244', 0)
$ gai.py 2001:db8:f00d::1:d
```

(continues on next page)

(continued from previous page)

```
AddressFamily.AF_INET6 ('2001:db8:f00d::1:d', 0, 0, 0)
$ gai.py www.google.com
AddressFamily.AF_INET6 ('2607:f8b0:4006:818::2004', 0, 0, 0)
AddressFamily.AF_INET ('172.217.10.132', 0)
```

It handles unusual cases, valid and invalid:

```
$ gai.py 10.0.0.256 # octet overflow
Invalid
$ gai.py not-exist.example.com # unresolvable
Invalid
$ gai.py fe80::1%eth0 # scoped
AddressFamily.AF_INET6 ('fe80::1%eth0', 0, 0, 2)
$ gai.py ::ffff:192.0.2.128 # IPv4-Mapped
AddressFamily.AF_INET6 ('::ffff:192.0.2.128', 0, 0, 0)
$ gai.py 0xc000027b # IPv4 in hex
AddressFamily.AF_INET ('192.0.2.123', 0)
$ gai.py 3221226198 # IPv4 in decimal
AddressFamily.AF_INET ('192.0.2.214', 0)
```

3.2.3 Transform Host & Network Endian

```
# little-endian machine
>>> import socket
>>> a = 1 # host endian
>>> socket.htons(a) # network endian
256
>>> socket.htonl(a) # network endian
16777216
>>> socket.ntohs(256) # host endian
1
>>> socket.ntohl(16777216) # host endian
1

# big-endian machine
>>> import socket
>>> a = 1 # host endian
>>> socket.htons(a) # network endian
1
>>> socket.htonl(a) # network endian
1L
>>> socket.ntohs(1) # host endian
1
>>> socket.ntohl(1) # host endian
1L
```

3.2.4 IP dotted-quad string & byte format convert

```
>>> import socket
>>> addr = socket.inet_aton('127.0.0.1')
>>> addr
'\x7f\x00\x00\x01'
>>> socket.inet_ntoa(addr)
'127.0.0.1'
```

3.2.5 Mac address & byte format convert

```
>>> import binascii
>>> mac = '00:11:32:3c:c3:0b'
>>> byte = binascii.unhexlify(mac.replace(':', ''))
>>> byte
'\x00\x11<\xc3\x0b'
>>> binascii.hexlify(byte)
'0011323cc30b'
```

3.2.6 Simple TCP Echo Server

```
import socket

class Server(object):
    def __init__(self, host, port):
        self._host = host
        self._port = port
    def __enter__(self):
        sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
        sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
        sock.bind((self._host, self._port))
        sock.listen(10)
        self._sock = sock
        return self._sock
    def __exit__(self, *exc_info):
        if exc_info[0]:
            import traceback
            traceback.print_exception(*exc_info)
        self._sock.close()

if __name__ == '__main__':
    host = 'localhost'
    port = 5566
    with Server(host, 5566) as s:
        while True:
            conn, addr = s.accept()
            msg = conn.recv(1024)
            conn.send(msg)
            conn.close()
```

output:

```
$ nc localhost 5566
Hello World
Hello World
```

3.2.7 Simple TCP Echo Server through IPv6

```
import contextlib
import socket

host = "::1"
port = 5566

@contextlib.contextmanager
def server(host, port):
    s = socket.socket(socket.AF_INET6, socket.SOCK_STREAM, 0)
    try:
        s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
        s.bind((host, port))
        s.listen(10)
        yield s
    finally:
        s.close()

with server(host, port) as s:
    try:
        while True:
            conn, addr = s.accept()
            msg = conn.recv(1024)

            if msg:
                conn.send(msg)

            conn.close()
    except KeyboardInterrupt:
        pass
```

output:

```
$ python3 ipv6.py &
[1] 25752
$ nc -6 ::1 5566
Hello IPv6
Hello IPv6
```

3.2.8 Disable IPv6 Only

```
#!/usr/bin/env python3

import contextlib
import socket

host = ":::"
port = 5566

@contextlib.contextmanager
def server(host: str, port: int):
    s = socket.socket(socket.AF_INET6, socket.SOCK_STREAM, 0)
    try:
        s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
        s.setsockopt(socket.IPPROTO_IPV6, socket.IPV6_V6ONLY, 0)
        s.bind((host, port))
        s.listen(10)
        yield s
    finally:
        s.close()

with server(host, port) as s:
    try:
        while True:
            conn, addr = s.accept()
            remote = conn.getpeername()
            print(remote)
            msg = conn.recv(1024)

            if msg:
                conn.send(msg)

            conn.close()
    except KeyboardInterrupt:
        pass
```

output:

```
$ python3 ipv6.py &
[1] 23914
$ nc -4 127.0.0.1 5566
('::ffff:127.0.0.1', 42604, 0, 0)
Hello IPv4
Hello IPv4
$ nc -6 ::1 5566
('::1', 50882, 0, 0)
Hello IPv6
Hello IPv6
$ nc -6 fe80::a00:27ff:fe9b:50ee%enp0s3 5566
('fe80::a00:27ff:fe9b:50ee%enp0s3', 42042, 0, 2)
Hello IPv6
```

(continues on next page)

(continued from previous page)

```
Hello IPv6
```

3.2.9 Simple TCP Echo Server Via SocketServer

```
>>> import SocketServer
>>> bh = SocketServer.BaseRequestHandler
>>> class handler(bh):
...     def handle(self):
...         data = self.request.recv(1024)
...         print(self.client_address)
...         self.request.sendall(data)
...
>>> host = ('localhost', 5566)
>>> s = SocketServer.TCPServer(
...     host, handler)
>>> s.serve_forever()
```

output:

```
$ nc localhost 5566
Hello World
Hello World
```

3.2.10 Simple TLS/SSL TCP Echo Server

```
import socket
import ssl

sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM, 0)
sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
sock.bind(('localhost', 5566))
sock.listen(10)

sslctx = ssl.SSLContext(ssl.PROTOCOL_TLSv1)
sslctx.load_cert_chain(certfile='./root-ca.crt',
                      keyfile='./root-ca.key')

try:
    while True:
        conn, addr = sock.accept()
        sslconn = sslctx.wrap_socket(conn, server_side=True)
        msg = sslconn.recv(1024)
        if msg:
            sslconn.send(msg)
        sslconn.close()
finally:
    sock.close()
```

output:

```
# console 1
$ openssl genrsa -out root-ca.key 2048
$ openssl req -x509 -new -nodes -key root-ca.key -days 365 -out root-ca.crt
$ python3 ssl_tcp_server.py

# console 2
$ openssl s_client -connect localhost:5566
...
Hello SSL
Hello SSL
read:errno=0
```

3.2.11 Set ciphers on TLS/SSL TCP Echo Server

```
import socket
import json
import ssl

sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM, 0)
sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
sock.bind(('localhost', 5566))
sock.listen(10)

sslctx = ssl.SSLContext(ssl.PROTOCOL_SSLv23)
sslctx.load_cert_chain(certfile='cert.pem',
                      keyfile='key.pem')

# set ssl ciphers
sslctx.set_ciphers('ECDH-ECDSA-AES128-GCM-SHA256')
print(json.dumps(sslctx.get_ciphers(), indent=2))

try:
    while True:
        conn, addr = sock.accept()
        sslconn = sslctx.wrap_socket(conn, server_side=True)
        msg = sslconn.recv(1024)
        if msg:
            sslconn.send(msg)
        sslconn.close()
finally:
    sock.close()
```

output:

```
$ openssl ecparam -out key.pem -genkey -name prime256v1
$ openssl req -x509 -new -key key.pem -out cert.pem
$ python3 tls.py&
[2] 64565
[
  {
    "id": 50380845,
    "name": "ECDH-ECDSA-AES128-GCM-SHA256",
```

(continues on next page)

(continued from previous page)

```

    "protocol": "TLSv1/SSLv3",
    "description": "ECDH-ECDSA-AES128-GCM-SHA256 TLSv1.2 Kx=ECDH/ECDSA Au=ECDH_
↪Enc=AEAGCM(128) Mac=AEAD",
    "strength_bits": 128,
    "alg_bits": 128
}
]
$ openssl s_client -connect localhost:5566 -cipher "ECDH-ECDSA-AES128-GCM-SHA256"
...
---
Hello ECDH-ECDSA-AES128-GCM-SHA256
Hello ECDH-ECDSA-AES128-GCM-SHA256
read:errno=0

```

3.2.12 Simple UDP Echo Server

```

import socket

class UDPServer(object):
    def __init__(self, host, port):
        self._host = host
        self._port = port

    def __enter__(self):
        sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
        sock.bind((self._host, self._port))
        self._sock = sock
        return sock

    def __exit__(self, *exc_info):
        if exc_info[0]:
            import traceback
            traceback.print_exception(*exc_info)
        self._sock.close()

if __name__ == '__main__':
    host = 'localhost'
    port = 5566
    with UDPServer(host, port) as s:
        while True:
            msg, addr = s.recvfrom(1024)
            s.sendto(msg, addr)

```

output:

```

$ nc -u localhost 5566
Hello World
Hello World

```


3.2.13 Simple UDP Echo Server Via SocketServer

```
>>> import SocketServer
>>> bh = SocketServer.BaseRequestHandler
>>> class handler(bh):
...     def handle(self):
...         m,s = self.request
...         s.sendto(m,self.client_address)
...         print(self.client_address)
...
>>> host = ('localhost', 5566)
>>> s = SocketServer.UDPServer(
...     host, handler)
>>> s.serve_forever()
```

output:

```
$ nc -u localhost 5566
Hello World
Hello World
```

3.2.14 Simple UDP client - Sender

```
>>> import socket
>>> import time
>>> sock = socket.socket(
...     socket.AF_INET,
...     socket.SOCK_DGRAM)
>>> host = ('localhost', 5566)
>>> while True:
...     sock.sendto("Hello\n", host)
...     time.sleep(5)
... 
```

output:

```
$ nc -lu localhost 5566
Hello
Hello
```

3.2.15 Broadcast UDP Packets

```
>>> import socket
>>> import time
>>> sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
>>> sock.bind(('', 0))
>>> sock.setsockopt(socket.SOL_SOCKET, socket.SO_BROADCAST,1)
>>> while True:
...     m = '{0}\n'.format(time.time())
...     sock.sendto(m, ('<broadcast>', 5566))
```

(continues on next page)

(continued from previous page)

```
...     time.sleep(5)
...
```

output:

```
$ nc -k -w 1 -ul 5566
1431473025.72
```

3.2.16 Simple UNIX Domain Socket

```
import socket
import contextlib
import os

@contextlib.contextmanager
def DomainServer(addr):
    try:
        if os.path.exists(addr):
            os.unlink(addr)
        sock = socket.socket(socket.AF_UNIX, socket.SOCK_STREAM)
        sock.bind(addr)
        sock.listen(10)
        yield sock
    finally:
        sock.close()
        if os.path.exists(addr):
            os.unlink(addr)

addr = "./domain.sock"
with DomainServer(addr) as sock:
    while True:
        conn, _ = sock.accept()
        msg = conn.recv(1024)
        conn.send(msg)
        conn.close()
```

output:

```
$ nc -U ./domain.sock
Hello
Hello
```

3.2.17 Simple duplex processes communication

```
import os
import socket

child, parent = socket.socketpair()
pid = os.fork()
try:

    if pid == 0:
        print('chlid pid: {}'.format(os.getpid()))

        child.send(b'Hello Parent')
        msg = child.recv(1024)
        print('p[{}] ---> c[{}]: {}'.format(
            os.getppid(), os.getpid(), msg))
    else:
        print('parent pid: {}'.format(os.getpid()))

        # simple echo server (parent)
        msg = parent.recv(1024)
        print('c[{}] ---> p[{}]: {}'.format(
            pid, os.getpid(), msg))
        parent.send(msg)

except KeyboardInterrupt:
    pass
finally:
    child.close()
    parent.close()
```

output:

```
$ python3 socketpair_demo.py
parent pid: 9497
chlid pid: 9498
c[9498] ---> p[9497]: b'Hello Parent'
p[9497] ---> c[9498]: b'Hello Parent'
```

3.2.18 Simple Asynchronous TCP Server - Thread

```
>>> from threading import Thread
>>> import socket
>>> def work(conn):
...     while True:
...         msg = conn.recv(1024)
...         conn.send(msg)
...
>>> sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
>>> sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
>>> sock.bind(('localhost', 5566))
```

(continues on next page)

(continued from previous page)

```
>>> sock.listen(5)
>>> while True:
...     conn,addr = sock.accept()
...     t=Thread(target=work, args=(conn,))
...     t.daemon=True
...     t.start()
... 
```

output: (bash 1)

```
$ nc localhost 5566
Hello
Hello
```

output: (bash 2)

```
$ nc localhost 5566
Ker Ker
Ker Ker
```

3.2.19 Simple Asynchronous TCP Server - select

```
from select import select
import socket

host = ('localhost', 5566)
sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
sock.bind(host)
sock.listen(5)
rl = [sock]
wl = []
ml = {}
try:
    while True:
        r, w, _ = select(rl, wl, [])
        # process ready to read
        for _ in r:
            if _ == sock:
                conn, addr = sock.accept()
                rl.append(conn)
            else:
                msg = _.recv(1024)
                ml[_.fileno()] = msg
                wl.append(_)
        # process ready to write
        for _ in w:
            msg = ml[_.fileno()]
            _.send(msg)
            wl.remove(_)
            del ml[_.fileno()]
```

(continues on next page)

(continued from previous page)

```
except:
    sock.close()
```

output: (bash 1)

```
$ nc localhost 5566
Hello
Hello
```

output: (bash 2)

```
$ nc localhost 5566
Ker Ker
Ker Ker
```

3.2.20 Simple Asynchronous TCP Server - poll

```
from __future__ import print_function, unicode_literals

import socket
import select
import contextlib

host = 'localhost'
port = 5566

con = {}
req = {}
resp = {}

@contextlib.contextmanager
def Server(host,port):
    try:
        s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
        s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
        s.setblocking(False)
        s.bind((host,port))
        s.listen(10)
        yield s
    except socket.error:
        print("Get socket error")
        raise
    finally:
        if s: s.close()

@contextlib.contextmanager
def Poll():
    try:
        e = select.poll()
        yield e
```

(continues on next page)

(continued from previous page)

```
    finally:
        for fd, c in con.items():
            e.unregister(fd)
            c.close()

def accept(server, poll):
    conn, addr = server.accept()
    conn.setblocking(False)
    fd = conn.fileno()
    poll.register(fd, select.POLLIN)
    req[fd] = conn
    con[fd] = conn

def recv(fd, poll):
    if fd not in req:
        return

    conn = req[fd]
    msg = conn.recv(1024)
    if msg:
        resp[fd] = msg
        poll.modify(fd, select.POLLOUT)
    else:
        conn.close()
        del con[fd]

    del req[fd]

def send(fd, poll):
    if fd not in resp:
        return

    conn = con[fd]
    msg = resp[fd]
    b = 0
    total = len(msg)
    while total > b:
        l = conn.send(msg)
        msg = msg[l:]
        b += l

    del resp[fd]
    req[fd] = conn
    poll.modify(fd, select.POLLIN)

try:
    with Server(host, port) as server, Poll() as poll:

        poll.register(server.fileno())
```

(continues on next page)

(continued from previous page)

```

while True:
    events = poll.poll(1)
    for fd, e in events:
        if fd == server.fileno():
            accept(server, poll)
        elif e & (select.POLLIN | select.POLLPRI):
            recv(fd, poll)
        elif e & select.POLLOUT:
            send(fd, poll)
except KeyboardInterrupt:
    pass

```

output: (bash 1)

```

$ python3 poll.py &
[1] 3036
$ nc localhost 5566
Hello poll
Hello poll
Hello Python Socket Programming
Hello Python Socket Programming

```

output: (bash 2)

```

$ nc localhost 5566
Hello Python
Hello Python
Hello Awesome Python
Hello Awesome Python

```

3.2.21 Simple Asynchronous TCP Server - epoll

```

from __future__ import print_function, unicode_literals

import socket
import select
import contextlib

host = 'localhost'
port = 5566

con = {}
req = {}
resp = {}

@contextlib.contextmanager
def Server(host, port):
    try:
        s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)

```

(continues on next page)

(continued from previous page)

```

        s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
        s.setblocking(False)
        s.bind((host, port))
        s.listen(10)
        yield s
    except socket.error:
        print("Get socket error")
        raise
    finally:
        if s: s.close()

@contextlib.contextmanager
def Epoll():
    try:
        e = select.epoll()
        yield e
    finally:
        for fd in con: e.unregister(fd)
        e.close()

def accept(server, epoll):
    conn, addr = server.accept()
    conn.setblocking(0)
    fd = conn.fileno()
    epoll.register(fd, select.EPOLLIN)
    req[fd] = conn
    con[fd] = conn

def recv(fd, epoll):
    if fd not in req:
        return

    conn = req[fd]
    msg = conn.recv(1024)
    if msg:
        resp[fd] = msg
        epoll.modify(fd, select.EPOLLOUT)
    else:
        conn.close()
        del con[fd]

    del req[fd]

def send(fd, epoll):
    if fd not in resp:
        return

    conn = con[fd]

```

(continues on next page)

(continued from previous page)

```

msg = resp[fd]
b = 0
total = len(msg)
while total > b:
    l = conn.send(msg)
    msg = msg[l:]
    b += l

del resp[fd]
req[fd] = conn
epoll.modify(fd, select.EPOLLIN)

try:
    with Server(host, port) as server, Epoll() as epoll:

        epoll.register(server.fileno())

        while True:
            events = epoll.poll(1)
            for fd, e in events:
                if fd == server.fileno():
                    accept(server, epoll)
                elif e & select.EPOLLIN:
                    recv(fd, epoll)
                elif e & select.EPOLLOUT:
                    send(fd, epoll)
except KeyboardInterrupt:
    pass

```

output: (bash 1)

```

$ python3 epoll.py &
[1] 3036
$ nc localhost 5566
Hello epoll
Hello epoll
Hello Python Socket Programming
Hello Python Socket Programming

```

output: (bash 2)

```

$ nc localhost 5566
Hello Python
Hello Python
Hello Awesome Python
Hello Awesome Python

```

3.2.22 Simple Asynchronous TCP Server - kqueue

```
from __future__ import print_function, unicode_literals

import socket
import select
import contextlib

if not hasattr(select, 'kqueue'):
    print("Not support kqueue")
    exit(1)

host = 'localhost'
port = 5566

con = {}
req = {}
resp = {}

@contextlib.contextmanager
def Server(host, port):
    try:
        s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
        s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
        s.setblocking(False)
        s.bind((host, port))
        s.listen(10)
        yield s
    except socket.error:
        print("Get socket error")
        raise
    finally:
        if s: s.close()

@contextlib.contextmanager
def Kqueue():
    try:
        kq = select.kqueue()
        yield kq
    finally:
        kq.close()
        for fd, c in con.items(): c.close()

def accept(server, kq):
    conn, addr = server.accept()
    conn.setblocking(False)
    fd = conn.fileno()
    ke = select.kevent(conn.fileno(),
                       select.KQ_FILTER_READ,
                       select.KQ_EV_ADD)
```

(continues on next page)

(continued from previous page)

```

kq.control([ke], 0)
req[fd] = conn
con[fd] = conn

def recv(fd, kq):
    if fd not in req:
        return

    conn = req[fd]
    msg = conn.recv(1024)
    if msg:
        resp[fd] = msg
        # remove read event
        ke = select.kevent(fd,
                           select.KQ_FILTER_READ,
                           select.KQ_EV_DELETE)
        kq.control([ke], 0)
        # add write event
        ke = select.kevent(fd,
                           select.KQ_FILTER_WRITE,
                           select.KQ_EV_ADD)
        kq.control([ke], 0)
        req[fd] = conn
        con[fd] = conn
    else:
        conn.close()
        del con[fd]

    del req[fd]

def send(fd, kq):
    if fd not in resp:
        return

    conn = con[fd]
    msg = resp[fd]
    b = 0
    total = len(msg)
    while total > b:
        l = conn.send(msg)
        msg = msg[l:]
        b += l

    del resp[fd]
    req[fd] = conn
    # remove write event
    ke = select.kevent(fd,
                       select.KQ_FILTER_WRITE,
                       select.KQ_EV_DELETE)
    kq.control([ke], 0)

```

(continues on next page)

(continued from previous page)

```

# add read event
ke = select.kevent(fd,
                    select.KQ_FILTER_READ,
                    select.KQ_EV_ADD)
kq.control([ke], 0)

try:
    with Server(host, port) as server, Kqueue() as kq:

        max_events = 1024
        timeout = 1

        ke = select.kevent(server.fileno(),
                            select.KQ_FILTER_READ,
                            select.KQ_EV_ADD)

        kq.control([ke], 0)
        while True:
            events = kq.control(None, max_events, timeout)
            for e in events:
                fd = e.ident
                if fd == server.fileno():
                    accept(server, kq)
                elif e.filter == select.KQ_FILTER_READ:
                    recv(fd, kq)
                elif e.filter == select.KQ_FILTER_WRITE:
                    send(fd, kq)
except KeyboardInterrupt:
    pass

```

output: (bash 1)

```

$ python3 kqueue.py &
[1] 3036
$ nc localhost 5566
Hello kqueue
Hello kqueue
Hello Python Socket Programming
Hello Python Socket Programming

```

output: (bash 2)

```

$ nc localhost 5566
Hello Python
Hello Python
Hello Awesome Python
Hello Awesome Python

```

3.2.23 High-Level API - selectors

```
# Python3.4+ only
# Reference: selectors
import selectors
import socket
import contextlib

@contextlib.contextmanager
def Server(host, port):
    try:
        s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
        s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
        s.bind((host, port))
        s.listen(10)
        sel = selectors.DefaultSelector()
        yield s, sel
    except socket.error:
        print("Get socket error")
        raise
    finally:
        if s:
            s.close()

def read_handler(conn, sel):
    msg = conn.recv(1024)
    if msg:
        conn.send(msg)
    else:
        sel.unregister(conn)
        conn.close()

def accept_handler(s, sel):
    conn, _ = s.accept()
    sel.register(conn, selectors.EVENT_READ, read_handler)

host = 'localhost'
port = 5566
with Server(host, port) as (s, sel):
    sel.register(s, selectors.EVENT_READ, accept_handler)
    while True:
        events = sel.select()
        for sel_key, m in events:
            handler = sel_key.data
            handler(sel_key.fileobj, sel)
```

output: (bash 1)

```
$ nc localhost 5566
Hello
Hello
```

output: (bash 1)

```
$ nc localhost 5566
Hi
Hi
```

3.2.24 Simple Non-blocking TLS/SSL socket via selectors

```
import socket
import selectors
import contextlib
import ssl

from functools import partial

sslctx = ssl.create_default_context(ssl.Purpose.CLIENT_AUTH)
sslctx.load_cert_chain(certfile="cert.pem", keyfile="key.pem")

@contextlib.contextmanager
def Server(host, port):
    try:
        s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
        s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
        s.bind((host, port))
        s.listen(10)
        sel = selectors.DefaultSelector()
        yield s, sel
    except socket.error:
        print("Get socket error")
        raise
    finally:
        if s: s.close()
        if sel: sel.close()

def accept(s, sel):
    conn, _ = s.accept()
    sslconn = sslctx.wrap_socket(conn,
                                server_side=True,
                                do_handshake_on_connect=False)
    sel.register(sslconn, selectors.EVENT_READ, do_handshake)

def do_handshake(sslconn, sel):
    sslconn.do_handshake()
    sel.modify(sslconn, selectors.EVENT_READ, read)

def read(sslconn, sel):
    msg = sslconn.recv(1024)
    if msg:
        sel.modify(sslconn,
                   selectors.EVENT_WRITE,
```

(continues on next page)

(continued from previous page)

```

        partial(write, msg=msg))
    else:
        sel.unregister(sslconn)
        sslconn.close()

def write(sslconn, sel, msg=None):
    if msg:
        sslconn.send(msg)
        sel.modify(sslconn, selectors.EVENT_READ, read)

host = 'localhost'
port = 5566
try:
    with Server(host, port) as (s,sel):
        sel.register(s, selectors.EVENT_READ, accept)
        while True:
            events = sel.select()
            for sel_key, m in events:
                handler = sel_key.data
                handler(sel_key.fileobj, sel)
except KeyboardInterrupt:
    pass

```

output:

```

# console 1
$ openssl genrsa -out key.pem 2048
$ openssl req -x509 -new -nodes -key key.pem -days 365 -out cert.pem
$ python3 ssl_tcp_server.py &
$ openssl s_client -connect localhost:5566
...
---
Hello TLS
Hello TLS

# console 2
$ openssl s_client -connect localhost:5566
...
---
Hello SSL
Hello SSL

```

3.2.25 “socketpair” - Similar to PIPE

```
import socket
import os
import time

c_s, p_s = socket.socketpair()
try:
    pid = os.fork()
except OSError:
    print("Fork Error")
    raise

if pid:
    # parent process
    c_s.close()
    while True:
        p_s.sendall("Hi! Child!")
        msg = p_s.recv(1024)
        print(msg)
        time.sleep(3)
    os.wait()
else:
    # child process
    p_s.close()
    while True:
        msg = c_s.recv(1024)
        print(msg)
        c_s.sendall("Hi! Parent!")
```

output:

```
$ python ex.py
Hi! Child!
Hi! Parent!
Hi! Child!
Hi! Parent!
...
```

3.2.26 Using sendfile to copy

```
# need python 3.3 or above
from __future__ import print_function, unicode_literals

import os
import sys

if len(sys.argv) != 3:
    print("Usage: cmd src dst")
    exit(1)
```

(continues on next page)

(continued from previous page)

```

src = sys.argv[1]
dst = sys.argv[2]

with open(src, 'r') as s, open(dst, 'w') as d:
    st = os.fstat(s.fileno())

    offset = 0
    count = 4096
    s_len = st.st_size

    sfd = s.fileno()
    dfd = d.fileno()

    while s_len > 0:
        ret = os.sendfile(dfd, sfd, offset, count)
        offset += ret
        s_len -= ret

```

output:

```

$ dd if=/dev/urandom of=dd.in bs=1M count=1024
1024+0 records in
1024+0 records out
1073741824 bytes (1.1 GB, 1.0 GiB) copied, 108.02 s, 9.9 MB/s
$ python3 sendfile.py dd.in dd.out
$ md5sum dd.in
e79afdd6aba71b7174142c0bbc289674 dd.in
$ md5sum dd.out
e79afdd6aba71b7174142c0bbc289674 dd.out

```

3.2.27 Sending a file through sendfile

```

# need python 3.5 or above
from __future__ import print_function, unicode_literals

import os
import sys
import time
import socket
import contextlib

@contextlib.contextmanager
def server(host, port):
    try:
        s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
        s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
        s.bind((host, port))
        s.listen(10)
        yield s
    finally:

```

(continues on next page)

(continued from previous page)

```
s.close()

@contextlib.contextmanager
def client(host, port):
    try:
        c = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
        c.connect((host, port))
        yield c
    finally:
        c.close()

def do_sendfile(fout, fin, count, fin_len):
    l = fin_len
    offset = 0
    while l > 0:
        ret = fout.sendfile(fin, offset, count)
        offset += ret
        l -= ret

def do_recv(fout, fin):
    while True:
        data = fin.recv(4096)

        if not data: break

        fout.write(data)

host = 'localhost'
port = 5566

if len(sys.argv) != 3:
    print("usage: cmd src dst")
    exit(1)

src = sys.argv[1]
dst = sys.argv[2]
offset = 0

pid = os.fork()

if pid == 0:
    # client
    time.sleep(3)
    with client(host, port) as c, open(src, 'rb') as f:
        fd = f.fileno()
        st = os.fstat(fd)
        count = 4096
```

(continues on next page)

(continued from previous page)

```

        flen = st.st_size
        do_sendfile(c, f, count, flen)

else:
    # server
    with server(host, port) as s, open(dst, 'wb') as f:
        conn, addr = s.accept()
        do_recv(f, conn)

```

output:

```

$ dd if=/dev/urandom of=dd.in bs=1M count=512
512+0 records in
512+0 records out
536870912 bytes (537 MB, 512 MiB) copied, 3.17787 s, 169 MB/s
$ python3 sendfile.py dd.in dd.out
$ md5sum dd.in
eadfd96c85976b1f46385e89dfd9c4a8 dd.in
$ md5sum dd.out
eadfd96c85976b1f46385e89dfd9c4a8 dd.out

```

3.2.28 Linux kernel Crypto API - AF_ALG

```

# need python 3.6 or above & Linux >=2.6.38
import socket
import hashlib
import contextlib

@contextlib.contextmanager
def create_alg(typ, name):
    s = socket.socket(socket.AF_ALG, socket.SOCK_SEQPACKET, 0)
    try:
        s.bind((typ, name))
        yield s
    finally:
        s.close()

msg = b'Python is awesome!'

with create_alg('hash', 'sha256') as algo:
    op, _ = algo.accept()
    with op:
        op.sendall(msg)
        data = op.recv(512)
        print(data.hex())

    # check data
    h = hashlib.sha256(msg).digest()
    if h != data:
        raise Exception(f"sha256({h}) != af_alg({data})")

```

output:

```
$ python3 af_alg.py
9d50bcac2d5e33f936ec2db7dc7b6579cba8e1b099d77c31d8564df46f66bdf5
```

3.2.29 AES-CBC encrypt/decrypt via AF_ALG

```
# need python 3.6 or above & Linux >=4.3
import contextlib
import socket
import os

BS = 16 # Bytes
pad = lambda s: s + (BS - len(s) % BS) * \
    chr(BS - len(s) % BS).encode('utf-8')

upad = lambda s : s[0:-s[-1]]

@contextlib.contextmanager
def create_alg(typ, name):
    s = socket.socket(socket.AF_ALG, socket.SOCK_SEQPACKET, 0)
    try:
        s.bind((typ, name))
        yield s
    finally:
        s.close()

def encrypt(plaintext, key, iv):
    ciphertext = None
    with create_alg('skcipher', 'cbc(aes)') as algo:
        algo.setsockopt(socket.SOL_ALG, socket.ALG_SET_KEY, key)
        op, _ = algo.accept()
        with op:
            plaintext = pad(plaintext)
            op.sendmsg_afalg([plaintext],
                             op=socket.ALG_OP_ENCRYPT,
                             iv=iv)
            ciphertext = op.recv(len(plaintext))

    return ciphertext

def decrypt(ciphertext, key, iv):
    plaintext = None
    with create_alg('skcipher', 'cbc(aes)') as algo:
        algo.setsockopt(socket.SOL_ALG, socket.ALG_SET_KEY, key)
        op, _ = algo.accept()
        with op:
            op.sendmsg_afalg([ciphertext],
                             op=socket.ALG_OP_DECRYPT,
```

(continues on next page)

(continued from previous page)

```

        iv=iv)
    plaintext = op.recv(len(ciphertext))

    return upad(plaintext)

key = os.urandom(32)
iv = os.urandom(16)

plaintext = b"Demo AF_ALG"
ciphertext = encrypt(plaintext, key, iv)
plaintext = decrypt(ciphertext, key, iv)

print(ciphertext.hex())
print(plaintext)

```

output:

```

$ python3 aes_cbc.py
01910e4bd6932674dba9bebd4fdf6cf2
b'Demo AF_ALG'

```

3.2.30 AES-GCM encrypt/decrypt via AF_ALG

```

# need python 3.6 or above & Linux >=4.9
import contextlib
import socket
import os

@contextlib.contextmanager
def create_alg(typ, name):
    s = socket.socket(socket.AF_ALG, socket.SOCK_SEQPACKET, 0)
    try:
        s.bind((typ, name))
        yield s
    finally:
        s.close()

def encrypt(key, iv, assoc, taglen, plaintext):
    """ doing aes-gcm encrypt

    :param key: the aes symmetric key
    :param iv: initial vector
    :param assoc: associated data (integrity protection)
    :param taglen: authenticator tag len
    :param plaintext: plain text data
    """

    assoclen = len(assoc)

```

(continues on next page)

(continued from previous page)

```

ciphertext = None
tag = None

with create_alg('aead', 'gcm(aes)') as algo:
    algo.setsockopt(socket.SOL_ALG,
                     socket.ALG_SET_KEY, key)
    algo.setsockopt(socket.SOL_ALG,
                     socket.ALG_SET_AEAD_AUTHSIZE,
                     None,
                     assoclen)

    op, _ = algo.accept()
    with op:
        msg = assoc + plaintext
        op.sendmsg_afalg([msg],
                         op=socket.ALG_OP_ENCRYPT,
                         iv=iv,
                         assoclen=assoclen)

        res = op.recv(assoclen + len(plaintext) + taglen)
        ciphertext = res[assoclen:-taglen]
        tag = res[-taglen:]

    return ciphertext, tag

def decrypt(key, iv, assoc, tag, ciphertext):
    """ doing aes-gcm decrypt

    :param key: the AES symmetric key
    :param iv: initial vector
    :param assoc: associated data (integrity protection)
    :param tag: the GCM authenticator tag
    :param ciphertext: cipher text data
    """
    plaintext = None
    assoclen = len(assoc)

    with create_alg('aead', 'gcm(aes)') as algo:
        algo.setsockopt(socket.SOL_ALG,
                         socket.ALG_SET_KEY, key)
        algo.setsockopt(socket.SOL_ALG,
                         socket.ALG_SET_AEAD_AUTHSIZE,
                         None,
                         assoclen)

        op, _ = algo.accept()
        with op:
            msg = assoc + ciphertext + tag
            op.sendmsg_afalg([msg],
                             op=socket.ALG_OP_DECRYPT, iv=iv,
                             assoclen=assoclen)

```

(continues on next page)

(continued from previous page)

```

        taglen = len(tag)
        res = op.recv(len(msg) - taglen)
        plaintext = res[assoclen:]

    return plaintext

key = os.urandom(16)
iv = os.urandom(12)
assoc = os.urandom(16)

plaintext = b"Hello AES-GCM"
ciphertext, tag = encrypt(key, iv, assoc, 16, plaintext)
plaintext = decrypt(key, iv, assoc, tag, ciphertext)

print(ciphertext.hex())
print(plaintext)

```

output:

```

$ python3 aes_gcm.py
2e27b67234e01bcb0ab6b451f4f870ce
b'Hello AES-GCM'

```

3.2.31 AES-GCM encrypt/decrypt file with sendfile

```

# need python 3.6 or above & Linux >=4.9
import contextlib
import socket
import sys
import os

@contextlib.contextmanager
def create_alg(typ, name):
    s = socket.socket(socket.AF_ALG, socket.SOCK_SEQPACKET, 0)
    try:
        s.bind((typ, name))
        yield s
    finally:
        s.close()

def encrypt(key, iv, assoc, taglen, pfile):
    assoclen = len(assoc)
    ciphertext = None
    tag = None

    pfd = pfile.fileno()
    offset = 0
    st = os.fstat(pfd)
    totalbytes = st.st_size

```

(continues on next page)

(continued from previous page)

```

with create_alg('aead', 'gcm(aes)') as algo:
    algo.setsockopt(socket.SOL_ALG,
                    socket.ALG_SET_KEY, key)
    algo.setsockopt(socket.SOL_ALG,
                    socket.ALG_SET_AEAD_AUTHSIZE,
                    None,
                    assoclen)

    op, _ = algo.accept()
    with op:
        op.sendmsg_afalg(op=socket.ALG_OP_ENCRYPT,
                        iv=iv,
                        assoclen=assoclen,
                        flags=socket.MSG_MORE)

        op.sendall(assoc, socket.MSG_MORE)

        # using sendfile to encrypt file data
        os.sendfile(op.fileno(), pfd, offset, totalbytes)

        res = op.recv(assoclen + totalbytes + taglen)
        ciphertext = res[assoclen:-taglen]
        tag = res[-taglen:]

    return ciphertext, tag


def decrypt(key, iv, assoc, tag, ciphertext):
    plaintext = None
    assoclen = len(assoc)

    with create_alg('aead', 'gcm(aes)') as algo:
        algo.setsockopt(socket.SOL_ALG,
                        socket.ALG_SET_KEY, key)
        algo.setsockopt(socket.SOL_ALG,
                        socket.ALG_SET_AEAD_AUTHSIZE,
                        None,
                        assoclen)

        op, _ = algo.accept()
        with op:
            msg = assoc + ciphertext + tag
            op.sendmsg_afalg([msg],
                            op=socket.ALG_OP_DECRYPT, iv=iv,
                            assoclen=assoclen)

            taglen = len(tag)
            res = op.recv(len(msg) - taglen)
            plaintext = res[assoclen:]

    return plaintext

```

(continues on next page)

(continued from previous page)

```

key = os.urandom(16)
iv  = os.urandom(12)
assoc = os.urandom(16)

if len(sys.argv) != 2:
    print("usage: cmd plain")
    exit(1)

plain = sys.argv[1]

with open(plain, 'r') as pf:
    ciphertext, tag = encrypt(key, iv, assoc, 16, pf)
    plaintext = decrypt(key, iv, assoc, tag, ciphertext)

    print(ciphertext.hex())
    print(plaintext)

```

output:

```

$ echo "Test AES-GCM with sendfile" > plain.txt
$ python3 aes_gcm.py plain.txt
b3800044520ed07fa7f20b29c2695bae9ab596065359db4f009dd6
b'Test AES-GCM with sendfile\n'

```

3.2.32 Compare the performance of AF_ALG to cryptography

```

# need python 3.6 or above & Linux >=4.9
import contextlib
import socket
import time
import os

from cryptography.hazmat.primitives.ciphers.aead import AESGCM

@contextlib.contextmanager
def create_alg(typ, name):
    s = socket.socket(socket.AF_ALG, socket.SOCK_SEQPACKET, 0)
    try:
        s.bind((typ, name))
        yield s
    finally:
        s.close()

def encrypt(key, iv, assoc, taglen, op, pfile, psize):
    assoclen = len(assoc)
    ciphertext = None
    tag = None
    offset = 0

```

(continues on next page)

(continued from previous page)

```

pfd = pfile.fileno()
totalbytes = psize

op.sendmsg_afalg(op=socket.ALG_OP_ENCRYPT,
                 iv=iv,
                 assoclen=assoclen,
                 flags=socket.MSG_MORE)

op.sendall(assoc, socket.MSG_MORE)

# using sendfile to encrypt file data
os.sendfile(op.fileno(), pfd, offset, totalbytes)

res = op.recv(assoclen + totalbytes + taglen)
ciphertext = res[assoclen:-taglen]
tag = res[-taglen:]

return ciphertext, tag

def decrypt(key, iv, assoc, tag, op, ciphertext):
    plaintext = None
    assoclen = len(assoc)

    msg = assoc + ciphertext + tag
    op.sendmsg_afalg([msg],
                    op=socket.ALG_OP_DECRYPT, iv=iv,
                    assoclen=assoclen)

    taglen = len(tag)
    res = op.recv(len(msg) - taglen)
    plaintext = res[assoclen:]

    return plaintext

key = os.urandom(16)
iv = os.urandom(12)
assoc = os.urandom(16)
assoclen = len(assoc)

count = 1000000
plain = "tmp.rand"

# crate a tmp file
with open(plain, 'wb') as f:
    f.write(os.urandom(4096))
    f.flush()

# profile AF_ALG with sendfile (zero-copy)
with open(plain, 'rb') as pf,\

```

(continues on next page)

(continued from previous page)

```

create_alg('aead', 'gcm(aes)') as enc_algo,\
create_alg('aead', 'gcm(aes)') as dec_algo:

enc_algo.setsockopt(socket.SOL_ALG,
                    socket.ALG_SET_KEY, key)
enc_algo.setsockopt(socket.SOL_ALG,
                    socket.ALG_SET_AEAD_AUTHSIZE,
                    None,
                    assoclen)

dec_algo.setsockopt(socket.SOL_ALG,
                    socket.ALG_SET_KEY, key)
dec_algo.setsockopt(socket.SOL_ALG,
                    socket.ALG_SET_AEAD_AUTHSIZE,
                    None,
                    assoclen)

enc_op, _ = enc_algo.accept()
dec_op, _ = dec_algo.accept()

st = os.fstat(pf.fileno())
psize = st.st_size

with enc_op, dec_op:

    s = time.time()

    for _ in range(count):
        ciphertext, tag = encrypt(key, iv, assoc, 16, enc_op, pf, psize)
        plaintext = decrypt(key, iv, assoc, tag, dec_op, ciphertext)

    cost = time.time() - s

    print(f"total cost time: {cost}. [AF_ALG]")

# profile cryptography (no zero-copy)
with open(plain, 'rb') as pf:

    aesgcm = AESGCM(key)

    s = time.time()

    for _ in range(count):
        pf.seek(0, 0)
        plaintext = pf.read()
        ciphertext = aesgcm.encrypt(iv, plaintext, assoc)
        plaintext = aesgcm.decrypt(iv, ciphertext, assoc)

    cost = time.time() - s

    print(f"total cost time: {cost}. [cryptography]")

```

(continues on next page)

(continued from previous page)

```
# clean up
os.remove(plain)
```

output:

```
$ python3 aes-gcm.py
total cost time: 15.317010641098022. [AF_ALG]
total cost time: 50.256704807281494. [cryptography]
```

3.2.33 Sniffer IP packets

```
from ctypes import *
import socket
import struct

# ref: IP protocol numbers
PROTO_MAP = {
    1 : "ICMP",
    2 : "IGMP",
    6 : "TCP",
    17: "UDP",
    27: "RDP"}

class IP(Structure):
    """ IP header Structure

    In linux api, it define as below:

    struct ip {
        u_char      ip_hl; /* header_len */
        u_char      ip_v; /* version */
        u_char      ip_tos; /* type of service */
        short       ip_len; /* total len */
        u_short     ip_id; /* identification */
        short       ip_off; /* offset field */
        u_char      ip_ttl; /* time to live */
        u_char      ip_p; /* protocol */
        u_short     ip_sum; /* checksum */
        struct in_addr ip_src; /* source */
        struct in_addr ip_dst; /* destination */
    };
    """
    _fields_ = [("ip_hl", c_ubyte, 4), # 4 bit
                ("ip_v", c_ubyte, 4), # 1 byte
                ("ip_tos", c_uint8), # 2 byte
                ("ip_len", c_uint16), # 4 byte
                ("ip_id", c_uint16), # 6 byte
                ("ip_off", c_uint16), # 8 byte
                ("ip_ttl", c_uint8), # 9 byte
```

(continues on next page)

(continued from previous page)

```

        ("ip_p" , c_uint8),      # 10 byte
        ("ip_sum", c_uint16),   # 12 byte
        ("ip_src", c_uint32),   # 16 byte
        ("ip_dst", c_uint32)]   # 20 byte

def __new__(cls, buf=None):
    return cls.from_buffer_copy(buf)
def __init__(self, buf=None):
    src = struct.pack("<L", self.ip_src)
    self.src = socket.inet_ntoa(src)
    dst = struct.pack("<L", self.ip_dst)
    self.dst = socket.inet_ntoa(dst)
    try:
        self.proto = PROTO_MAP[self.ip_p]
    except KeyError:
        print("{} Not in map".format(self.ip_p))
        raise

host = '0.0.0.0'
s = socket.socket(socket.AF_INET,
                  socket.SOCK_RAW,
                  socket.IPPROTO_ICMP)
s.setsockopt(socket.IPPROTO_IP, socket.IP_HDRINCL, 1)
s.bind((host, 0))

print("Sniffer start...")
try:
    while True:
        buf = s.recvfrom(65535)[0]
        ip_header = IP(buf[:20])
        print('{0}: {1} -> {2}'.format(ip_header.proto,
                                      ip_header.src,
                                      ip_header.dst))
except KeyboardInterrupt:
    s.close()

```

output: (bash 1)

```

python sniffer.py
Sniffer start...
ICMP: 127.0.0.1 -> 127.0.0.1
ICMP: 127.0.0.1 -> 127.0.0.1
ICMP: 127.0.0.1 -> 127.0.0.1

```

output: (bash 2)

```

$ ping -c 3 localhost
PING localhost (127.0.0.1): 56 data bytes
64 bytes from 127.0.0.1: icmp_seq=0 ttl=64 time=0.063 ms
64 bytes from 127.0.0.1: icmp_seq=1 ttl=64 time=0.087 ms
64 bytes from 127.0.0.1: icmp_seq=2 ttl=64 time=0.159 ms

```

(continues on next page)

(continued from previous page)

```

--- localhost ping statistics ---
3 packets transmitted, 3 packets received, 0.0% packet loss
round-trip min/avg/max/stddev = 0.063/0.103/0.159/0.041 ms

```

3.2.34 Sniffer TCP packet

```

#!/usr/bin/env python3.6
"""
Based on RFC-793, the following figure shows the TCP header format:

```

0										1										2										3									
0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1								
Source Port										Destination Port																													
Sequence Number																																							
Acknowledgment Number																																							
Data										U A P R S F																													
Offset										Reserved										R C S S Y I										Window									
																				G K H T N N																			
Checksum										Urgent Pointer																													
Options										Padding																													
data																																							

In linux api (uapi/linux/tcp.h), it defines the TCP header:

```

struct tcphdr {
    __be16 source;
    __be16 dest;
    __be32 seq;
    __be32 ack_seq;
#ifdef __LITTLE_ENDIAN_BITFIELD
    __u16  res1:4,
           doff:4,
           fin:1,
           syn:1,
           rst:1,
           psh:1,
           ack:1,
           urg:1,
           ece:1,
           cwr:1;
#elif defined(__BIG_ENDIAN_BITFIELD)
    __u16  doff:4,

```

(continues on next page)

(continued from previous page)

```

        res1:4,
        cwr:1,
        ece:1,
        urg:1,
        ack:1,
        psh:1,
        rst:1,
        syn:1,
        fin:1;
#else
#error      "Adjust your <asm/byteorder.h> defines"
#endif
    __be16  window;
    __sum16  check;
    __be16  urg_ptr;
};
"""

import sys
import socket
import platform

from struct import unpack
from contextlib import contextmanager

un = platform.system()
if un != "Linux":
    print(f"{un} is not supported!")
    sys.exit(1)

@contextmanager
def create_socket()::
    """ Create a TCP raw socket """
    s = socket.socket(socket.AF_INET,
                      socket.SOCK_RAW,
                      socket.IPPROTO_TCP)

    try:
        yield s
    finally:
        s.close()

try:
    with create_socket() as s:
        while True:
            pkt, addr = s.recvfrom(65535)

            # the first 20 bytes are ip header
            iphdr = unpack('!BBHHHBBH4s4s', pkt[0:20])
            iplen = (iphdr[0] & 0xf) * 4

            # the next 20 bytes are tcp header
            tcphdr = unpack('!HLLBBHHH', pkt[iplen:iplen+20])

```

(continues on next page)

(continued from previous page)

```

source = tcphdr[0]
dest = tcphdr[1]
seq = tcphdr[2]
ack_seq = tcphdr[3]
dr = tcphdr[4]
flags = tcphdr[5]
window = tcphdr[6]
check = tcphdr[7]
urg_ptr = tcphdr[8]

doff = dr >> 4
fin = flags & 0x01
syn = flags & 0x02
rst = flags & 0x04
psh = flags & 0x08
ack = flags & 0x10
urg = flags & 0x20
ece = flags & 0x40
cwr = flags & 0x80

tcplen = (doff) * 4
h_size = iplen + tcplen

#get data from the packet
data = pkt[h_size:]

if not data:
    continue

print("----- TCP_HEADER -----")
print(f"Source Port:      {source}")
print(f"Destination Port:   {dest}")
print(f"Sequence Number:     {seq}")
print(f"Acknowledgment Number: {ack_seq}")
print(f>Data offset:         {doff}")
print(f"FIN:                  {fin}")
print(f"SYN:                  {syn}")
print(f"RST:                  {rst}")
print(f"PSH:                  {psh}")
print(f"ACK:                  {ack}")
print(f"URG:                  {urg}")
print(f"ECE:                  {ece}")
print(f"CWR:                  {cwr}")
print(f"Window:              {window}")
print(f"Checksum:            {check}")
print(f"Urgent Point:        {urg_ptr}")
print("----- DATA -----")
print(data)

except KeyboardInterrupt:
    pass

```

output:


```
$ python3.6 tcp.py
----- TCP_HEADER -----
Source Port:      38352
Destination Port: 8000
Sequence Number:  2907801591
Acknowledgment Number: 398995857
Data offset:      8
FIN:              0
SYN:              0
RST:              0
PSH:              8
ACK:              16
URG:              0
ECE:              0
CWR:              0
Window:           342
Checksum:         65142
Urgent Point:     0
----- DATA -----
b'GET / HTTP/1.1\r\nHost: localhost:8000\r\nUser-Agent: curl/7.47.0\r\nAccept: */*\r\n\r\n'
↪n'
```

3.2.35 Sniffer ARP packet

```
"""
Ethernet Packet Header

struct ethhdr {
    unsigned char h_dest[ETH_ALEN]; /* destination eth addr */
    unsigned char h_source[ETH_ALEN]; /* source ether addr */
    __be16        h_proto;           /* packet type ID field */
} __attribute__((packed));

ARP Packet Header

struct arphdr {
    uint16_t htype; /* Hardware Type */
    uint16_t ptype; /* Protocol Type */
    u_char hlen; /* Hardware Address Length */
    u_char plen; /* Protocol Address Length */
    uint16_t opcode; /* Operation Code */
    u_char sha[6]; /* Sender hardware address */
    u_char spa[4]; /* Sender IP address */
    u_char tha[6]; /* Target hardware address */
    u_char tpa[4]; /* Target IP address */
};
"""

import socket
import struct
import binascii
```

(continues on next page)

(continued from previous page)

```

rawSocket = socket.socket(socket.AF_PACKET,
                           socket.SOCK_RAW,
                           socket.htons(0x0003))

while True:

    packet = rawSocket.recvfrom(2048)
    ethhdr = packet[0][0:14]
    eth = struct.unpack("!6s6s2s", ethhdr)

    arphdr = packet[0][14:42]
    arp = struct.unpack("2s2s1s1s2s6s4s6s4s", arphdr)
    # skip non-ARP packets
    ethtype = eth[2]
    if ethtype != '\x08\x06': continue

    print("----- ETHERNET_FRAME -----")
    print("Dest MAC:      ", binascii.hexlify(eth[0]))
    print("Source MAC:     ", binascii.hexlify(eth[1]))
    print("Type:           ", binascii.hexlify(ethtype))
    print("----- ARP_HEADER -----")
    print("Hardware type:   ", binascii.hexlify(arp[0]))
    print("Protocol type:   ", binascii.hexlify(arp[1]))
    print("Hardware size:   ", binascii.hexlify(arp[2]))
    print("Protocol size:   ", binascii.hexlify(arp[3]))
    print("Opcode:         ", binascii.hexlify(arp[4]))
    print("Source MAC:      ", binascii.hexlify(arp[5]))
    print("Source IP:       ", socket.inet_ntoa(arp[6]))
    print("Dest MAC:        ", binascii.hexlify(arp[7]))
    print("Dest IP:         ", socket.inet_ntoa(arp[8]))
    print("-----")

```

output:

```

$ python arp.py
----- ETHERNET_FRAME -----
Dest MAC:      ffffffff
Source MAC:    f0257252f5ca
Type:          0806
----- ARP_HEADER -----
Hardware type:  0001
Protocol type:  0800
Hardware size:  06
Protocol size:  04
Opcode:        0001
Source MAC:     f0257252f5ca
Source IP:      140.112.91.254
Dest MAC:       000000000000
Dest IP:        140.112.91.20
-----

```

3.3 Asyncio

Table of Contents

- *Asyncio*
 - *asyncio.run*
 - *Future like object*
 - *Future like object `__await__` other task*
 - *Patch loop runner `_run_once`*
 - *Put blocking task into Executor*
 - *Socket with asyncio*
 - *Event Loop with polling*
 - *Transport and Protocol*
 - *Transport and Protocol with SSL*
 - *Asynchronous Iterator*
 - *What is asynchronous iterator*
 - *Asynchronous context manager*
 - *What is asynchronous context manager*
 - *decorator `@asynccontextmanager`*
 - *Simple asyncio connection pool*
 - *Get domain name*
 - *Gather Results*
 - *Simple asyncio UDP echo server*
 - *Simple asyncio Web server*
 - *Simple HTTPS Web Server*
 - *Simple HTTPS Web server (low-level api)*
 - *TLS Upgrade*
 - *Using `sendfile`*
 - *Simple asyncio WSGI web server*

3.3.1 asyncio.run

New in Python 3.7

```
>>> import asyncio
>>> from concurrent.futures import ThreadPoolExecutor
>>> e = ThreadPoolExecutor()
>>> async def read_file(file_):
...     loop = asyncio.get_event_loop()
...     with open(file_) as f:
...         return (await loop.run_in_executor(e, f.read))
...
>>> ret = asyncio.run(read_file('/etc/passwd'))
```

3.3.2 Future like object

```
>>> import sys
>>> PY_35 = sys.version_info >= (3, 5)
>>> import asyncio
>>> loop = asyncio.get_event_loop()
>>> class SlowObj:
...     def __init__(self, n):
...         print("__init__")
...         self._n = n
...     if PY_35:
...         def __await__(self):
...             print("__await__ sleep({})".format(self._n))
...             yield from asyncio.sleep(self._n)
...             print("ok")
...             return self
...
>>> async def main():
...     obj = await SlowObj(3)
...
>>> loop.run_until_complete(main())
__init__
__await__ sleep(3)
ok
```

3.3.3 Future like object __await__ other task

```
>>> import sys
>>> PY_35 = sys.version_info >= (3, 5)
>>> import asyncio
>>> loop = asyncio.get_event_loop()
>>> async def slow_task(n):
...     await asyncio.sleep(n)
...
>>> class SlowObj:
...     def __init__(self, n):
```

(continues on next page)

(continued from previous page)

```

...     print("__init__")
...     self._n = n
...     if PY_35:
...         def __await__(self):
...             print("__await__")
...             yield from slow_task(self._n).__await__()
...             yield from asyncio.sleep(self._n)
...             print("ok")
...             return self
...
>>> async def main():
...     obj = await SlowObj(1)
...
>>> loop.run_until_complete(main())
__init__
__await__
ok

```

3.3.4 Patch loop runner `_run_once`

```

>>> import asyncio
>>> def _run_once(self):
...     num_tasks = len(self._scheduled)
...     print("num tasks in queue: {}".format(num_tasks))
...     super(asyncio.SelectorEventLoop, self)._run_once()
...
>>> EventLoop = asyncio.SelectorEventLoop
>>> EventLoop._run_once = _run_once
>>> loop = EventLoop()
>>> asyncio.set_event_loop(loop)
>>> async def task(n):
...     await asyncio.sleep(n)
...     print("sleep: {} sec".format(n))
...
>>> coro = loop.create_task(task(3))
>>> loop.run_until_complete(coro)
num tasks in queue: 0
num tasks in queue: 1
num tasks in queue: 0
sleep: 3 sec
num tasks in queue: 0
>>> loop.close()

```

3.3.5 Put blocking task into Executor

```
>>> import asyncio
>>> from concurrent.futures import ThreadPoolExecutor
>>> e = ThreadPoolExecutor()
>>> loop = asyncio.get_event_loop()
>>> async def read_file(file_):
...     with open(file_) as f:
...         data = await loop.run_in_executor(e, f.read)
...         return data
...
>>> task = loop.create_task(read_file('/etc/passwd'))
>>> ret = loop.run_until_complete(task)
```

3.3.6 Socket with asyncio

```
import asyncio
import socket

host = 'localhost'
port = 9527
loop = asyncio.get_event_loop()
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM, 0)
s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
s.setblocking(False)
s.bind((host, port))
s.listen(10)

async def handler(conn):
    while True:
        msg = await loop.sock_recv(conn, 1024)
        if not msg:
            break
        await loop.sock_sendall(conn, msg)
    conn.close()

async def server():
    while True:
        conn, addr = await loop.sock_accept(s)
        loop.create_task(handler(conn))

loop.create_task(server())
loop.run_forever()
loop.close()
```

output: (bash 1)

```
$ nc localhost 9527
Hello
Hello
```

output: (bash 2)

```
$ nc localhost 9527
World
World
```

3.3.7 Event Loop with polling

```
# using selectors
# ref: PyCon 2015 - David Beazley

import asyncio
import socket
import selectors
from collections import deque

@asyncio.coroutine
def read_wait(s):
    yield 'read_wait', s

@asyncio.coroutine
def write_wait(s):
    yield 'write_wait', s

class Loop:
    """Simple loop prototype"""

    def __init__(self):
        self.ready = deque()
        self.selector = selectors.DefaultSelector()

    @asyncio.coroutine
    def sock_accept(self, s):
        yield from read_wait(s)
        return s.accept()

    @asyncio.coroutine
    def sock_recv(self, c, mb):
        yield from read_wait(c)
        return c.recv(mb)

    @asyncio.coroutine
    def sock_sendall(self, c, m):
        while m:
            yield from write_wait(c)
            nsent = c.send(m)
            m = m[nsent:]

    def create_task(self, coro):
        self.ready.append(coro)

    def run_forever(self):
        while True:
```

(continues on next page)

(continued from previous page)

```

        self._run_once()

    def _run_once(self):
        while not self.ready:
            events = self.selector.select()
            for k, _ in events:
                self.ready.append(k.data)
                self.selector.unregister(k.fileobj)

        while self.ready:
            self.cur_t = ready.popleft()
            try:
                op, *a = self.cur_t.send(None)
                getattr(self, op)(*a)
            except StopIteration:
                pass

    def read_wait(self, s):
        self.selector.register(s, selectors.EVENT_READ, self.cur_t)

    def write_wait(self, s):
        self.selector.register(s, selectors.EVENT_WRITE, self.cur_t)

loop = Loop()
host = 'localhost'
port = 9527

s = socket.socket(
    socket.AF_INET,
    socket.SOCK_STREAM, 0)
s.setsockopt(
    socket.SOL_SOCKET,
    socket.SO_REUSEADDR, 1)
s.setblocking(False)
s.bind((host, port))
s.listen(10)

@asyncio.coroutine
def handler(c):
    while True:
        msg = yield from loop.sock_recv(c, 1024)
        if not msg:
            break
        yield from loop.sock_sendall(c, msg)
    c.close()

@asyncio.coroutine
def server():
    while True:
        c, addr = yield from loop.sock_accept(s)
        loop.create_task(handler(c))

```

(continues on next page)

(continued from previous page)

```
loop.create_task(server())  
loop.run_forever()
```

3.3.8 Transport and Protocol

```
import asyncio  
  
class EchoProtocol(asyncio.Protocol):  
  
    def connection_made(self, transport):  
        peername = transport.get_extra_info('peername')  
        print('Connection from {}'.format(peername))  
        self.transport = transport  
  
    def data_received(self, data):  
        msg = data.decode()  
        self.transport.write(data)  
  
loop = asyncio.get_event_loop()  
coro = loop.create_server(EchoProtocol, 'localhost', 5566)  
server = loop.run_until_complete(coro)  
  
try:  
    loop.run_forever()  
except:  
    loop.run_until_complete(server.wait_closed())  
finally:  
    loop.close()
```

output:

```
# console 1  
$ nc localhost 5566  
Hello  
Hello  
  
# console 2  
$ nc localhost 5566  
World  
World
```

3.3.9 Transport and Protocol with SSL

```
import asyncio
import ssl

def make_header():
    head = b"HTTP/1.1 200 OK\r\n"
    head += b"Content-Type: text/html\r\n"
    head += b"\r\n"
    return head

def make_body():
    resp = b"<html>"
    resp += b"<h1>Hello SSL</h1>"
    resp += b"</html>"
    return resp

sslctx = ssl.SSLContext(ssl.PROTOCOL_SSLv23)
sslctx.load_cert_chain(
    certfile="./root-ca.crt", keyfile="./root-ca.key"
)

class Service(asyncio.Protocol):
    def connection_made(self, tr):
        self.tr = tr
        self.total = 0

    def data_received(self, data):
        if data:
            resp = make_header()
            resp += make_body()
            self.tr.write(resp)
            self.tr.close()

async def start():
    server = await loop.create_server(
        Service, "localhost", 4433, ssl=sslctx
    )
    await server.wait_closed()

try:
    loop = asyncio.get_event_loop()
    loop.run_until_complete(start())
finally:
    loop.close()
```

output:

```
$ openssl genrsa -out root-ca.key 2048
$ openssl req -x509 -new -nodes -key root-ca.key -days 365 -out root-ca.crt
$ python3 ssl_web_server.py

# then open browser: https://localhost:4433
```

3.3.10 Asynchronous Iterator

```
# ref: PEP-0492
# need Python >= 3.5

>>> class AsyncIter:
...     def __init__(self, it):
...         self._it = iter(it)
...     def __aiter__(self):
...         return self
...     async def __anext__(self):
...         await asyncio.sleep(1)
...         try:
...             val = next(self._it)
...         except StopIteration:
...             raise StopAsyncIteration
...         return val
...
>>> async def foo():
...     it = [1, 2, 3]
...     async for _ in AsyncIter(it):
...         print(_)
...
>>> loop = asyncio.get_event_loop()
>>> loop.run_until_complete(foo())
1
2
3
```

3.3.11 What is asynchronous iterator

```
>>> import asyncio
>>> class AsyncIter:
...     def __init__(self, it):
...         self._it = iter(it)
...     def __aiter__(self):
...         return self
...     async def __anext__(self):
...         await asyncio.sleep(1)
...         try:
...             val = next(self._it)
...         except StopIteration:
...             raise StopAsyncIteration
```

(continues on next page)

(continued from previous page)

```

...         return val
...
>>> async def foo():
...     _ = [1, 2, 3]
...     running = True
...     it = AsyncIter(_)
...     while running:
...         try:
...             res = await it.__anext__()
...             print(res)
...         except StopAsyncIteration:
...             running = False
...
>>> loop = asyncio.get_event_loop()
>>> loop.run_until_complete(loop.create_task(foo()))
1
2
3

```

3.3.12 Asynchronous context manager

```

# ref: PEP-0492
# need Python >= 3.5

>>> class AsyncCtxMgr:
...     async def __aenter__(self):
...         await asyncio.sleep(3)
...         print("__anter__")
...         return self
...     async def __aexit__(self, *exc):
...         await asyncio.sleep(1)
...         print("__aexit__")
...
>>> async def hello():
...     async with AsyncCtxMgr() as m:
...         print("hello block")
...
>>> async def world():
...     print("world block")
...
>>> t = loop.create_task(world())
>>> loop.run_until_complete(hello())
world block
__anter__
hello block
__aexit__

```

3.3.13 What is asynchronous context manager

```
>>> import asyncio
>>> class AsyncManager:
...     async def __aenter__(self):
...         await asyncio.sleep(5)
...         print("__aenter__")
...     async def __aexit__(self, *exc_info):
...         await asyncio.sleep(3)
...         print("__aexit__")
...
>>> async def foo():
...     import sys
...     mgr = AsyncManager()
...     await mgr.__aenter__()
...     print("body")
...     await mgr.__aexit__(*sys.exc_info())
...
>>> loop = asyncio.get_event_loop()
>>> loop.run_until_complete(loop.create_task(foo()))
__aenter__
body
__aexit__
```

3.3.14 decorator @asynccontextmanager

New in Python 3.7

- [Issue 29679](#) - Add `@contextlib.asynccontextmanager`

```
>>> import asyncio
>>> from contextlib import asynccontextmanager
>>> @asynccontextmanager
... async def coro(msg):
...     await asyncio.sleep(1)
...     yield msg
...     await asyncio.sleep(0.5)
...     print('done')
...
>>> async def main():
...     async with coro("Hello") as m:
...         await asyncio.sleep(1)
...         print(m)
...
>>> loop = asyncio.get_event_loop()
>>> loop.run_until_complete(main())
Hello
done
```

3.3.15 Simple asyncio connection pool

```
import asyncio
import socket
import uuid

class Transport:

    def __init__(self, loop, host, port):
        self.used = False

        self._loop = loop
        self._host = host
        self._port = port
        self._sock = socket.socket(
            socket.AF_INET, socket.SOCK_STREAM)
        self._sock.setblocking(False)
        self._uuid = uuid.uuid1()

    async def connect(self):
        loop, sock = self._loop, self._sock
        host, port = self._host, self._port
        return (await loop.sock_connect(sock, (host, port)))

    async def sendall(self, msg):
        loop, sock = self._loop, self._sock
        return (await loop.sock_sendall(sock, msg))

    async def recv(self, buf_size):
        loop, sock = self._loop, self._sock
        return (await loop.sock_recv(sock, buf_size))

    def close(self):
        if self._sock: self._sock.close()

    @property
    def alive(self):
        ret = True if self._sock else False
        return ret

    @property
    def uuid(self):
        return self._uuid

class ConnectionPool:

    def __init__(self, loop, host, port, max_conn=3):
        self._host = host
        self._port = port
        self._max_conn = max_conn
        self._loop = loop
```

(continues on next page)

(continued from previous page)

```

        conns = [Transport(loop, host, port) for _ in range(max_conn)]
        self._conns = conns

    def __await__(self):
        for _c in self._conns:
            yield from _c.connect().__await__()
        return self

    def getconn(self, fut=None):
        if fut is None:
            fut = self._loop.create_future()

        for _c in self._conns:
            if _c.alive and not _c.used:
                _c.used = True
                fut.set_result(_c)
                break
        else:
            loop.call_soon(self.getconn, fut)

        return fut

    def release(self, conn):
        if not conn.used:
            return
        for _c in self._conns:
            if _c.uuid != conn.uuid:
                continue
            _c.used = False
            break

    def close(self):
        for _c in self._conns:
            _c.close()

async def handler(pool, msg):
    conn = await pool.getconn()
    byte = await conn.sendall(msg)
    mesg = await conn.recv(1024)
    pool.release(conn)
    return 'echo: {}'.format(mesg)

async def main(loop, host, port):
    try:
        # creat connection pool
        pool = await ConnectionPool(loop, host, port)

        # generate messages
        msgs = ['coro_{}'.format(_).encode('utf-8') for _ in range(5)]

```

(continues on next page)

(continued from previous page)

```

    # create tasks
    fs = [loop.create_task(handler(pool, _m)) for _m in msgs]

    # wait all tasks done
    done, pending = await asyncio.wait(fs)
    for _ in done: print(_.result())
finally:
    pool.close()

loop = asyncio.get_event_loop()
host = '127.0.0.1'
port = 9527

try:
    loop.run_until_complete(main(loop, host, port))
except KeyboardInterrupt:
    pass
finally:
    loop.close()

```

output:

```

$ ncat -l 9527 --keep-open --exec "/bin/cat" &
$ python3 conn_pool.py
echo: b'coro_1'
echo: b'coro_0'
echo: b'coro_2'
echo: b'coro_3'
echo: b'coro_4'

```

3.3.16 Get domain name

```

>>> import asyncio
>>> async def getaddrinfo(host, port):
...     loop = asyncio.get_event_loop()
...     return (await loop.getaddrinfo(host, port))
...
>>> addrs = asyncio.run(getaddrinfo('github.com', 443))
>>> for a in addrs:
...     family, typ, proto, name, sockaddr = a
...     print(sockaddr)
...
('192.30.253.113', 443)
('192.30.253.113', 443)
('192.30.253.112', 443)
('192.30.253.112', 443)

```


3.3.17 Gather Results

```
import asyncio
import ssl

path = ssl.get_default_verify_paths()
sslctx = ssl.SSLContext()
sslctx.verify_mode = ssl.CERT_REQUIRED
sslctx.check_hostname = True
sslctx.load_verify_locations(path.cafile)

async def fetch(host, port):
    r, w = await asyncio.open_connection(host, port, ssl=sslctx)
    req = "GET / HTTP/1.1\r\n"
    req += f"Host: {host}\r\n"
    req += "Connection: close\r\n"
    req += "\r\n"

    # send request
    w.write(req.encode())

    # recv response
    resp = ""
    while True:
        line = await r.readline()
        if not line:
            break
        line = line.decode("utf-8")
        resp += line

    # close writer
    w.close()
    await w.wait_closed()
    return resp

async def main():
    loop = asyncio.get_running_loop()
    url = ["python.org", "github.com", "google.com"]
    fut = [fetch(u, 443) for u in url]
    resps = await asyncio.gather(*fut)
    for r in resps:
        print(r.split("\r\n")[0])

asyncio.run(main())
```

output:

```
$ python fetch.py
HTTP/1.1 301 Moved Permanently
```

(continues on next page)

(continued from previous page)

```
HTTP/1.1 200 OK
HTTP/1.1 301 Moved Permanently
```

3.3.18 Simple asyncio UDP echo server

```
import asyncio
import socket

loop = asyncio.get_event_loop()

sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM, 0)
sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
sock.setblocking(False)

host = 'localhost'
port = 3553

sock.bind((host, port))

def recvfrom(loop, sock, n_bytes, fut=None, registered=False):
    fd = sock.fileno()
    if fut is None:
        fut = loop.create_future()
    if registered:
        loop.remove_reader(fd)

    try:
        data, addr = sock.recvfrom(n_bytes)
    except (BlockingIOError, InterruptedError):
        loop.add_reader(fd, recvfrom, loop, sock, n_bytes, fut, True)
    else:
        fut.set_result((data, addr))
    return fut

def sendto(loop, sock, data, addr, fut=None, registered=False):
    fd = sock.fileno()
    if fut is None:
        fut = loop.create_future()
    if registered:
        loop.remove_writer(fd)
    if not data:
        return

    try:
        n = sock.sendto(data, addr)
    except (BlockingIOError, InterruptedError):
        loop.add_writer(fd, sendto, loop, sock, data, addr, fut, True)
    else:
        fut.set_result(n)
    return fut
```

(continues on next page)

(continued from previous page)

```

async def udp_server(loop, sock):
    while True:
        data, addr = await recvfrom(loop, sock, 1024)
        n_bytes = await sendto(loop, sock, data, addr)

    try:
        loop.run_until_complete(udp_server(loop, sock))
    finally:
        loop.close()

```

output:

```

$ python3 udp_server.py
$ nc -u localhost 3553
Hello UDP
Hello UDP

```

3.3.19 Simple asyncio Web server

```

import asyncio
import socket

host = 'localhost'
port = 9527
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
s.setblocking(False)
s.bind((host, port))
s.listen(10)

loop = asyncio.get_event_loop()

def make_header():
    header = b"HTTP/1.1 200 OK\r\n"
    header += b"Content-Type: text/html\r\n"
    header += b"\r\n"
    return header

def make_body():
    resp = b'<html>'
    resp += b'<body><h3>Hello World</h3></body>'
    resp += b'</html>'
    return resp

async def handler(conn):
    req = await loop.sock_recv(conn, 1024)
    if req:
        resp = make_header()
        resp += make_body()

```

(continues on next page)

(continued from previous page)

```
        await loop.sock_sendall(conn, resp)
    conn.close()

async def server(sock, loop):
    while True:
        conn, addr = await loop.sock_accept(sock)
        loop.create_task(handler(conn))

try:
    loop.run_until_complete(server(s, loop))
except KeyboardInterrupt:
    pass
finally:
    loop.close()
    s.close()
# Then open browser with url: localhost:9527
```

3.3.20 Simple HTTPS Web Server

```
import asyncio
import ssl

ctx = ssl.SSLContext(ssl.PROTOCOL_TLS_SERVER)
ctx.load_cert_chain('crt.pem', 'key.pem')

async def conn(reader, writer):
    _ = await reader.read(1024)
    head = b"HTTP/1.1 200 OK\r\n"
    head += b"Content-Type: text/html\r\n"
    head += b"\r\n"

    body = b"<!doctype html>"
    body += b"<html>"
    body += b"<body><h1>Awesome Python</h1></body>"
    body += b"</html>"

    writer.write(head + body)
    writer.close()

async def main(host, port):
    srv = await asyncio.start_server(conn, host, port, ssl=ctx)
    async with srv:
        await srv.serve_forever()

asyncio.run(main('0.0.0.0', 8000))
```

3.3.21 Simple HTTPS Web server (low-level api)

```
import asyncio
import socket
import ssl

def make_header():
    head = b'HTTP/1.1 200 OK\r\n'
    head += b'Content-type: text/html\r\n'
    head += b'\r\n'
    return head

def make_body():
    resp = b'<html>'
    resp += b'<h1>Hello SSL</h1>'
    resp += b'</html>'
    return resp

sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM, 0)
sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
sock.setblocking(False)
sock.bind(('localhost', 4433))
sock.listen(10)

sslctx = ssl.SSLContext(ssl.PROTOCOL_SSLv23)
sslctx.load_cert_chain(certfile='./root-ca.crt',
                      keyfile='./root-ca.key')

def do_handshake(loop, sock, waiter):
    sock_fd = sock.fileno()
    try:
        sock.do_handshake()
    except ssl.SSLWantReadError:
        loop.remove_reader(sock_fd)
        loop.add_reader(sock_fd, do_handshake,
                        loop, sock, waiter)
        return
    except ssl.SSLWantWriteError:
        loop.remove_writer(sock_fd)
        loop.add_writer(sock_fd, do_handshake,
                        loop, sock, waiter)
        return

    loop.remove_reader(sock_fd)
    loop.remove_writer(sock_fd)
    waiter.set_result(None)

def handle_read(loop, conn, waiter):
    try:
        req = conn.recv(1024)
    except ssl.SSLWantReadError:
```

(continues on next page)

(continued from previous page)

```

        loop.remove_reader(conn.fileno())
        loop.add_reader(conn.fileno(), handle_read,
                        loop, conn, waiter)

        return
    loop.remove_reader(conn.fileno())
    waiter.set_result(req)

def handle_write(loop, conn, msg, waiter):
    try:
        resp = make_header()
        resp += make_body()
        ret = conn.send(resp)
    except ssl.SSLWantReadError:
        loop.remove_writer(conn.fileno())
        loop.add_writer(conn.fileno(), handle_write,
                        loop, conn, waiter)

        return
    loop.remove_writer(conn.fileno())
    conn.close()
    waiter.set_result(None)

async def server(loop):
    while True:
        conn, addr = await loop.sock_accept(sock)
        conn.setblocking(False)
        sslconn = sslctx.wrap_socket(conn,
                                     server_side=True,
                                     do_handshake_on_connect=False)

        # wait SSL handshake
        waiter = loop.create_future()
        do_handshake(loop, sslconn, waiter)
        await waiter

        # wait read request
        waiter = loop.create_future()
        handle_read(loop, sslconn, waiter)
        msg = await waiter

        # wait write response
        waiter = loop.create_future()
        handle_write(loop, sslconn, msg, waiter)
        await waiter

loop = asyncio.get_event_loop()
try:
    loop.run_until_complete(server(loop))
finally:
    loop.close()

```

output:

```
# console 1

$ openssl genrsa -out root-ca.key 2048
$ openssl req -x509 -new -nodes -key root-ca.key -days 365 -out root-ca.crt
$ python3 Simple_https_server.py

# console 2

$ curl https://localhost:4433 -v \
> --resolve localhost:4433:127.0.0.1 \
> --cacert ~/test/root-ca.crt
```

3.3.22 TLS Upgrade

New in Python 3.7

```
import asyncio
import ssl

class HttpClient(asyncio.Protocol):
    def __init__(self, on_con_lost):
        self.on_con_lost = on_con_lost
        self.resp = b""

    def data_received(self, data):
        self.resp += data

    def connection_lost(self, exc):
        resp = self.resp.decode()
        print(resp.split("\r\n")[0])
        self.on_con_lost.set_result(True)

async def main():
    paths = ssl.get_default_verify_paths()
    sslctx = ssl.SSLContext()
    sslctx.verify_mode = ssl.CERT_REQUIRED
    sslctx.check_hostname = True
    sslctx.load_verify_locations(paths.cafile)

    loop = asyncio.get_running_loop()
    on_con_lost = loop.create_future()

    tr, proto = await loop.create_connection(
        lambda: HttpClient(on_con_lost), "github.com", 443
    )
    new_tr = await loop.start_tls(tr, proto, sslctx)
    req = f"GET / HTTP/1.1\r\n"
    req += "Host: github.com\r\n"
    req += "Connection: close\r\n"
```

(continues on next page)

(continued from previous page)

```

req += "\r\n"
new_tr.write(req.encode())

await on_con_lost
new_tr.close()

asyncio.run(main())

```

output:

```

$ python3 --version
Python 3.7.0
$ python3 https.py
HTTP/1.1 200 OK

```

3.3.23 Using sendfile

New in Python 3.7

```

import asyncio

path = "index.html"

async def conn(reader, writer):

    loop = asyncio.get_event_loop()
    _ = await reader.read(1024)

    with open(path, "rb") as f:
        tr = writer.transport
        head = b"HTTP/1.1 200 OK\r\n"
        head += b"Content-Type: text/html\r\n"
        head += b"\r\n"

        tr.write(head)
        await loop.sendfile(tr, f)
        writer.close()

async def main(host, port):
    # run a simple http server
    srv = await asyncio.start_server(conn, host, port)
    async with srv:
        await srv.serve_forever()

asyncio.run(main("0.0.0.0", 8000))

```

output:

```

$ echo '<!doctype html><h1>Awesome Python</h1>' > index.html
$ python http.py &

```

(continues on next page)

(continued from previous page)

```
[2] 60506
$ curl http://localhost:8000
<!doctype html><h1>Awesome Python</h1>
```

3.3.24 Simple asyncio WSGI web server

```
# ref: PEP333

import asyncio
import socket
import io
import sys

from flask import Flask, Response

host = 'localhost'
port = 9527
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
s.setblocking(False)
s.bind((host, port))
s.listen(10)

loop = asyncio.get_event_loop()

class WSGIServer(object):

    def __init__(self, sock, app):
        self._sock = sock
        self._app = app
        self._header = []

    def parse_request(self, req):
        """ HTTP Request Format:

        GET /hello.htm HTTP/1.1\r\n
        Accept-Language: en-us\r\n
        ...
        Connection: Keep-Alive\r\n
        """
        # bytes to string
        req_info = req.decode('utf-8')
        first_line = req_info.splitlines()[0]
        method, path, ver = first_line.split()
        return method, path, ver

    def get_environ(self, req, method, path):
        env = {}

        # Required WSGI variables
```

(continues on next page)

(continued from previous page)

```

env['wsgi.version']      = (1, 0)
env['wsgi.url_scheme']   = 'http'
env['wsgi.input']        = req
env['wsgi.errors']       = sys.stderr
env['wsgi.multithread']   = False
env['wsgi.multiprocess'] = False
env['wsgi.run_once']     = False

# Required CGI variables
env['REQUEST_METHOD']    = method    # GET
env['PATH_INFO']         = path      # /hello
env['SERVER_NAME']       = host      # localhost
env['SERVER_PORT']       = str(port) # 9527
return env

def start_response(self, status, resp_header, exc_info=None):
    header = [('Server', 'WSGIServer 0.2')]
    self.headers_set = [status, resp_header + header]

async def finish_response(self, conn, data, headers):
    status, resp_header = headers

    # make header
    resp = 'HTTP/1.1 {0}\r\n'.format(status)
    for header in resp_header:
        resp += '{0}: {1}\r\n'.format(*header)
    resp += '\r\n'

    # make body
    resp += '{0}'.format(data)
    try:
        await loop.sock_sendall(conn, str.encode(resp))
    finally:
        conn.close()

async def run_server(self):
    while True:
        conn, addr = await loop.sock_accept(self._sock)
        loop.create_task(self.handle_request(conn))

async def handle_request(self, conn):
    # get request data
    req = await loop.sock_recv(conn, 1024)
    if req:
        method, path, ver = self.parse_request(req)
        # get environment
        env = self.get_environ(req, method, path)
        # get application execute result
        res = self._app(env, self.start_response)
        res = [_.decode('utf-8') for _ in list(res)]
        res = ''.join(res)
        loop.create_task(

```

(continues on next page)

(continued from previous page)

```
        self.finish_response(conn, res, self.headers_set))

app = Flask(__name__)

@app.route('/hello')
def hello():
    return Response("Hello WSGI", mimetype="text/plain")

server = WSGIServer(s, app.wsgi_app)
try:
    loop.run_until_complete(server.run_server())
except:
    pass
finally:
    loop.close()

# Then open browser with url: localhost:9527/hello
```

3.4 Concurrency

Table of Contents

- *Concurrency*
 - *Execute a shell command*
 - *Create a thread via “threading”*
 - *Performance Problem - GIL*
 - *Consumer and Producer*
 - *Thread Pool Template*
 - *Using multiprocessing ThreadPool*
 - *Mutex lock*
 - *Deadlock*
 - *Implement “Monitor”*
 - *Control primitive resources*
 - *Ensure tasks has done*
 - *Thread-safe priority queue*
 - *Multiprocessing*
 - *Custom multiprocessing map*
 - *Graceful way to kill all child processes*
 - *Simple round-robin scheduler*
 - *Scheduler with blocking function*

- *PoolExecutor*
- *How to use ThreadPoolExecutor?*
- *What does “with ThreadPoolExecutor” work?*
- *Future Object*
- *Future error handling*

3.4.1 Execute a shell command

```
# get stdout, stderr, returncode

>>> from subprocess import Popen, PIPE
>>> args = ['time', 'echo', 'hello python']
>>> ret = Popen(args, stdout=PIPE, stderr=PIPE)
>>> out, err = ret.communicate()
>>> out
b'hello python\n'
>>> err
b'          0.00 real          0.00 user          0.00 sys\n'
>>> ret.returncode
0
```

3.4.2 Create a thread via “threading”

```
>>> from threading import Thread
>>> class Worker(Thread):
...     def __init__(self, id):
...         super(Worker, self).__init__()
...         self._id = id
...     def run(self):
...         print("I am worker %d" % self._id)
...
>>> t1 = Worker(1)
>>> t2 = Worker(2)
>>> t1.start(); t2.start()
I am worker 1
I am worker 2

# using function could be more flexible
>>> def Worker(worker_id):
...     print("I am worker %d" % worker_id)
...
>>> from threading import Thread
>>> t1 = Thread(target=Worker, args=(1,))
>>> t2 = Thread(target=Worker, args=(2,))
>>> t1.start()
I am worker 1
I am worker 2
```

3.4.3 Performance Problem - GIL

```
# GIL - Global Interpreter Lock
# see: Understanding the Python GIL
>>> from threading import Thread
>>> def profile(func):
...     def wrapper(*args, **kwargs):
...         import time
...         start = time.time()
...         func(*args, **kwargs)
...         end = time.time()
...         print(end - start)
...         return wrapper
...
>>> @profile
... def nothread():
...     fib(35)
...     fib(35)
...
>>> @profile
... def hasthread():
...     t1=Thread(target=fib, args=(35,))
...     t2=Thread(target=fib, args=(35,))
...     t1.start(); t2.start()
...     t1.join(); t2.join()
...
>>> nothread()
9.51164007187
>>> hasthread()
11.3131771088
# !Thread get bad Performance
# since cost on context switch
```

3.4.4 Consumer and Producer

```
# This architecture make concurrency easy
>>> from threading import Thread
>>> from Queue import Queue
>>> from random import random
>>> import time
>>> q = Queue()
>>> def fib(n):
...     if n<=2:
...         return 1
...     return fib(n-1)+fib(n-2)
...
>>> def producer():
...     while True:
...         wt = random()*5
...         time.sleep(wt)
...         q.put((fib,35))
```

(continues on next page)

(continued from previous page)

```

...
>>> def consumer():
...     while True:
...         task,arg = q.get()
...         print(task(arg))
...         q.task_done()
...
>>> t1 = Thread(target=producer)
>>> t2 = Thread(target=consumer)
>>> t1.start();t2.start()

```

3.4.5 Thread Pool Template

```

# producer and consumer architecture
from Queue import Queue
from threading import Thread

class Worker(Thread):
    def __init__(self,queue):
        super(Worker, self).__init__()
        self._q = queue
        self.daemon = True
        self.start()
    def run(self):
        while True:
            f,args,kwargs = self._q.get()
            try:
                print(f(*args, **kwargs))
            except Exception as e:
                print(e)
            self._q.task_done()

class ThreadPool(object):
    def __init__(self, num_t=5):
        self._q = Queue(num_t)
        # Create Worker Thread
        for _ in range(num_t):
            Worker(self._q)
    def add_task(self,f,*args,**kwargs):
        self._q.put((f, args, kwargs))
    def wait_complete(self):
        self._q.join()

def fib(n):
    if n <= 2:
        return 1
    return fib(n-1)+fib(n-2)

if __name__ == '__main__':
    pool = ThreadPool()

```

(continues on next page)

(continued from previous page)

```

for _ in range(3):
    pool.add_task(fib, 35)
pool.wait_complete()

```

3.4.6 Using multiprocessing ThreadPool

```

# ThreadPool is not in python doc
>>> from multiprocessing.pool import ThreadPool
>>> pool = ThreadPool(5)
>>> pool.map(lambda x: x**2, range(5))
[0, 1, 4, 9, 16]

```

Compare with “map” performance

```

# pool will get bad result since GIL
import time
from multiprocessing.pool import \
    ThreadPool

pool = ThreadPool(10)
def profile(func):
    def wrapper(*args, **kwargs):
        print(func.__name__)
        s = time.time()
        func(*args, **kwargs)
        e = time.time()
        print("cost: {0}".format(e-s))
    return wrapper

@profile
def pool_map():
    res = pool.map(lambda x:x**2,
                   range(999999))

@profile
def ordinary_map():
    res = map(lambda x:x**2,
              range(999999))

pool_map()
ordinary_map()

```

output:

```

$ python test_threadpool.py
pool_map
cost: 0.562669038773
ordinary_map
cost: 0.38525390625

```

3.4.7 Mutex lock

Simplest synchronization primitive lock

```
>>> from threading import Thread
>>> from threading import Lock
>>> lock = Lock()
>>> def getlock(id):
...     lock.acquire()
...     print("task{0} get".format(id))
...     lock.release()
...
>>> t1=Thread(target=getlock,args=(1,))
>>> t2=Thread(target=getlock,args=(2,))
>>> t1.start();t2.start()
task1 get
task2 get

# using lock manager
>>> def getlock(id):
...     with lock:
...         print("task%d get" % id)
...
>>> t1=Thread(target=getlock,args=(1,))
>>> t2=Thread(target=getlock,args=(2,))
>>> t1.start();t2.start()
task1 get
task2 get
```

3.4.8 Deadlock

Happen when more than one mutex lock.

```
>>> import threading
>>> import time
>>> lock1 = threading.Lock()
>>> lock2 = threading.Lock()
>>> def task1():
...     with lock1:
...         print("get lock1")
...         time.sleep(3)
...         with lock2:
...             print("No deadlock")
...
>>> def task2():
...     with lock2:
...         print("get lock2")
...         with lock1:
...             print("No deadlock")
...
>>> t1=threading.Thread(target=task1)
>>> t2=threading.Thread(target=task2)
```

(continues on next page)

(continued from previous page)

```
>>> t1.start();t2.start()
get lock1
get lock2

>>> t1.isAlive()
True
>>> t2.isAlive()
True
```

3.4.9 Implement “Monitor”

Using RLock

```
# ref: An introduction to Python Concurrency - David Beazley
from threading import Thread
from threading import RLock
import time

class monitor(object):
    lock = RLock()
    def foo(self,tid):
        with monitor.lock:
            print("%d in foo" % tid)
            time.sleep(5)
            self.ker(tid)

    def ker(self,tid):
        with monitor.lock:
            print("%d in ker" % tid)
m = monitor()
def task1(id):
    m.foo(id)

def task2(id):
    m.ker(id)

t1 = Thread(target=task1,args=(1,))
t2 = Thread(target=task2,args=(2,))
t1.start()
t2.start()
t1.join()
t2.join()
```

output:

```
$ python monitor.py
1 in foo
1 in ker
2 in ker
```

3.4.10 Control primitive resources

Using Semaphore

```
from threading import Thread
from threading import Semaphore
from random import random
import time

# limit resource to 3
sema = Semaphore(3)
def foo(tid):
    with sema:
        print("%d acquire sema" % tid)
        wt = random()*5
        time.sleep(wt)
        print("%d release sema" % tid)

threads = []
for _t in range(5):
    t = Thread(target=foo,args=(_t,))
    threads.append(t)
    t.start()
for _t in threads:
    _t.join()
```

output:

```
python semaphore.py
0 acquire sema
1 acquire sema
2 acquire sema
0 release sema
3 acquire sema
2 release sema
4 acquire sema
1 release sema
4 release sema
3 release sema
```

3.4.11 Ensure tasks has done

Using 'event'

```
from threading import Thread
from threading import Event
import time

e = Event()

def worker(id):
    print("%d wait event" % id)
```

(continues on next page)

(continued from previous page)

```

    e.wait()
    print("%d get event set" % id)

t1=Thread(target=worker,args=(1,))
t2=Thread(target=worker,args=(2,))
t3=Thread(target=worker,args=(3,))
t1.start()
t2.start()
t3.start()

# wait sleep task(event) happen
time.sleep(3)
e.set()

```

output:

```

python event.py
1 wait event
2 wait event
3 wait event
2 get event set
  3 get event set
1 get event set

```

3.4.12 Thread-safe priority queue

Using ‘condition’

```

import threading
import heapq
import time
import random

class PriorityQueue(object):
    def __init__(self):
        self._q = []
        self._count = 0
        self._cv = threading.Condition()

    def __str__(self):
        return str(self._q)

    def __repr__(self):
        return self._q

    def put(self, item, priority):
        with self._cv:
            heapq.heappush(self._q, (-priority, self._count, item))
            self._count += 1
            self._cv.notify()

```

(continues on next page)

(continued from previous page)

```

def pop(self):
    with self._cv:
        while len(self._q) == 0:
            print("wait...")
            self._cv.wait()
        ret = heapq.heappop(self._q)[-1]
    return ret

priq = PriorityQueue()
def producer():
    while True:
        print(priq.pop())

def consumer():
    while True:
        time.sleep(3)
        print("consumer put value")
        priority = random.random()
        priq.put(priority,priority*10)

for _ in range(3):
    priority = random.random()
    priq.put(priority,priority*10)

t1=threading.Thread(target=producer)
t2=threading.Thread(target=consumer)
t1.start();t2.start()
t1.join();t2.join()

```

output:

```

python3 thread_safe.py
0.6657491871045683
0.5278797439991247
0.20990624606296315
wait...
consumer put value
0.09123101305407577
wait...

```

3.4.13 Multiprocessing

Solving GIL problem via processes

```

>>> from multiprocessing import Pool
>>> def fib(n):
...     if n <= 2:
...         return 1
...     return fib(n-1) + fib(n-2)
...
>>> def profile(func):

```

(continues on next page)

(continued from previous page)

```

...     def wrapper(*args, **kwargs):
...         import time
...         start = time.time()
...         func(*args, **kwargs)
...         end = time.time()
...         print(end - start)
...     return wrapper
...
>>> @profile
... def nomultiprocess():
...     map(fib,[35]*5)
...
>>> @profile
... def hasmultiprocess():
...     pool = Pool(5)
...     pool.map(fib,[35]*5)
...
>>> nomultiprocess()
23.8454811573
>>> hasmultiprocess()
13.2433719635

```

3.4.14 Custom multiprocessing map

```

from multiprocessing import Process, Pipe
from itertools import izip

def spawn(f):
    def fun(pipe,x):
        pipe.send(f(x))
        pipe.close()
    return fun

def parmap(f,X):
    pipe=[Pipe() for x in X]
    proc=[Process(target=spawn(f),
        args=(c,x))
        for x,(p,c) in izip(X,pipe)]
    [p.start() for p in proc]
    [p.join() for p in proc]
    return [p.recv() for (p,c) in pipe]

print(parmap(lambda x:x**x,range(1,5)))

```

3.4.15 Graceful way to kill all child processes

```
from __future__ import print_function

import signal
import os
import time

from multiprocessing import Process, Pipe

NUM_PROCESS = 10

def aurora(n):
    while True:
        time.sleep(n)

if __name__ == "__main__":
    procs = [Process(target=aurora, args=(x,))
              for x in range(NUM_PROCESS)]
    try:
        for p in procs:
            p.daemon = True
            p.start()
        [p.join() for p in procs]
    finally:
        for p in procs:
            if not p.is_alive(): continue
            os.kill(p.pid, signal.SIGKILL)
```

3.4.16 Simple round-robin scheduler

```
>>> def fib(n):
...     if n <= 2:
...         return 1
...     return fib(n-1)+fib(n-2)
...
>>> def gen_fib(n):
...     for _ in range(1,n+1):
...         yield fib(_)
...
>>> t=[gen_fib(5),gen_fib(3)]
>>> from collections import deque
>>> tasks = deque()
>>> tasks.extend(t)
>>> def run(tasks):
...     while tasks:
...         try:
...             task = tasks.popleft()
...             print(task.next())
...             tasks.append(task)
...         except StopIteration:
```

(continues on next page)

(continued from previous page)

```

...     print("done")
...
>>> run(tasks)
1
1
1
1
2
2
3
done
5
done

```

3.4.17 Scheduler with blocking function

```

# ref: PyCon 2015 - David Beazley
import socket
from select import select
from collections import deque

tasks = deque()
r_wait = {}
s_wait = {}

def fib(n):
    if n <= 2:
        return 1
    return fib(n-1)+fib(n-2)

def run():
    while any([tasks,r_wait,s_wait]):
        while not tasks:
            # polling
            rr, sr, _ = select(r_wait, s_wait, {})
            for _ in rr:
                tasks.append(r_wait.pop(_))
            for _ in sr:
                tasks.append(s_wait.pop(_))
        try:
            task = tasks.popleft()
            why, what = task.next()
            if why == 'recv':
                r_wait[what] = task
            elif why == 'send':
                s_wait[what] = task
            else:
                raise RuntimeError
        except StopIteration:
            pass

```

(continues on next page)

(continued from previous page)

```
def fib_server():
    sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
    sock.bind(('localhost', 5566))
    sock.listen(5)
    while True:
        yield 'recv', sock
        c, a = sock.accept()
        tasks.append(fib_handler(c))

def fib_handler(client):
    while True:
        yield 'recv', client
        req = client.recv(1024)
        if not req:
            break
        resp = fib(int(req))
        yield 'send', client
        client.send(str(resp)+'\n')
    client.close()

tasks.append(fib_server())
run()
```

output: (bash 1)

```
$ nc localhost 5566
20
6765
```

output: (bash 2)

```
$ nc localhost 5566
10
55
```

3.4.18 PoolExecutor

```
# python2.x is module futures on PyPI
# new in Python3.2
>>> from concurrent.futures import \
...     ThreadPoolExecutor
>>> def fib(n):
...     if n<=2:
...         return 1
...     return fib(n-1) + fib(n-2)
...
>>> with ThreadPoolExecutor(3) as e:
...     res= e.map(fib,[1,2,3,4,5])
...     for _ in res:
```

(continues on next page)

(continued from previous page)

```

...         print(_, end=' ')
...
1 1 2 3 5 >>>
# result is generator?!
>>> with ThreadPoolExecutor(3) as e:
...     res = e.map(fib, [1,2,3])
...     inspect.isgenerator(res)
...
True

# demo GIL
from concurrent import futures
import time

def fib(n):
    if n <= 2:
        return 1
    return fib(n-1) + fib(n-2)

def thread():
    s = time.time()
    with futures.ThreadPoolExecutor(2) as e:
        res = e.map(fib, [35]*2)
        for _ in res:
            print(_)
    e = time.time()
    print("thread cost: {}".format(e-s))

def process():
    s = time.time()
    with futures.ProcessPoolExecutor(2) as e:
        res = e.map(fib, [35]*2)
        for _ in res:
            print(_)
    e = time.time()
    print("pocess cost: {}".format(e-s))

# bash> python3 -i test.py
>>> thread()
9227465
9227465
thread cost: 12.550225019454956
>>> process()
9227465
9227465
pocess cost: 5.538189888000488

```

3.4.19 How to use ThreadPoolExecutor?

```
from concurrent.futures import ThreadPoolExecutor

def fib(n):
    if n <= 2:
        return 1
    return fib(n - 1) + fib(n - 2)

with ThreadPoolExecutor(max_workers=3) as ex:
    futs = []
    for x in range(3):
        futs.append(ex.submit(fib, 30+x))

    res = [fut.result() for fut in futs]

print(res)
```

output:

```
$ python3 thread_pool_ex.py
[832040, 1346269, 2178309]
```

3.4.20 What does “with ThreadPoolExecutor” work?

```
from concurrent import futures

def fib(n):
    if n <= 2:
        return 1
    return fib(n-1) + fib(n-2)

with futures.ThreadPoolExecutor(3) as e:
    fut = e.submit(fib, 30)
    res = fut.result()
    print(res)

# equal to

e = futures.ThreadPoolExecutor(3)
fut = e.submit(fib, 30)
fut.result()
e.shutdown(wait=True)
print(res)
```

output:

```
$ python3 thread_pool_exec.py
832040
832040
```

3.4.21 Future Object

```
# future: deferred computation
# add_done_callback
from concurrent import futures

def fib(n):
    if n <= 2:
        return 1
    return fib(n-1) + fib(n-2)

def handler(future):
    res = future.result()
    print("res: {}".format(res))

def thread_v1():
    with futures.ThreadPoolExecutor(3) as e:
        for _ in range(3):
            f = e.submit(fib, 30+_)
            f.add_done_callback(handler)
        print("end")

def thread_v2():
    to_do = []
    with futures.ThreadPoolExecutor(3) as e:
        for _ in range(3):
            fut = e.submit(fib, 30+_)
            to_do.append(fut)
        for _f in futures.as_completed(to_do):
            res = _f.result()
            print("res: {}".format(res))
    print("end")
```

output:

```
$ python3 -i fut.py
>>> thread_v1()
res: 832040
res: 1346269
res: 2178309
end
>>> thread_v2()
res: 832040
res: 1346269
res: 2178309
end
```

3.4.22 Future error handling

```
from concurrent import futures

def spam():
    raise RuntimeError

def handler(future):
    print("callback handler")
    try:
        res = future.result()
    except RuntimeError:
        print("get RuntimeError")

def thread_spam():
    with futures.ThreadPoolExecutor(2) as e:
        f = e.submit(spam)
        f.add_done_callback(handler)
```

output:

```
$ python -i fut_err.py
>>> thread_spam()
callback handler
get RuntimeError
```

3.5 SQLAlchemy

Table of Contents

- *SQLAlchemy*
 - *Set a database URL*
 - *Sqlalchemy Support DBAPI - PEP249*
 - *Transaction and Connect Object*
 - *Metadata - Generating Database Schema*
 - *Inspect - Get Database Information*
 - *Reflection - Loading Table from Existing Database*
 - *Print Create Table Statement with Indexes (SQL DDL)*
 - *Get Table from MetaData*
 - *Create all Tables Store in "MetaData"*
 - *Create Specific Table*
 - *Create table with same columns*
 - *Drop a Table*

- *Some Table Object Operation*
- *SQL Expression Language*
- *insert() - Create an “INSERT” Statement*
- *select() - Create a “SELECT” Statement*
- *join() - Joined Two Tables via “JOIN” Statement*
- *Fastest Bulk Insert in PostgreSQL via “COPY” Statement*
- *Bulk PostgreSQL Insert and Return Inserted IDs*
- *Update Multiple Rows*
- *Delete Rows from Table*
- *Check Table Existing*
- *Create multiple tables at once*
- *Create tables with dynamic columns (Table)*
- *Object Relational add data*
- *Object Relational update data*
- *Object Relational delete row*
- *Object Relational relationship*
- *Object Relational self association*
- *Object Relational basic query*
- *mapper: Map Table to class*
- *Get table dynamically*
- *Object Relational join two tables*
- *join on relationship and group_by count*
- *Create tables with dynamic columns (ORM)*
- *Close database connection*
- *Cannot use the object after close the session*
- *Hooks*

3.5.1 Set a database URL

```
from sqlalchemy.engine.url import URL

postgres_db = {'drivername': 'postgres',
               'username': 'postgres',
               'password': 'postgres',
               'host': '192.168.99.100',
               'port': 5432}
print(URL(**postgres_db))

sqlite_db = {'drivername': 'sqlite', 'database': 'db.sqlite'}
```

(continues on next page)

(continued from previous page)

```
print(URL(**sqlite_db))
```

output:

```
$ python sqlalchemy_url.py
postgres://postgres:postgres@192.168.99.100:5432
sqlite:///db.sqlite
```

3.5.2 Sqlalchemy Support DBAPI - PEP249

```
from sqlalchemy import create_engine

db_uri = "sqlite:///db.sqlite"
engine = create_engine(db_uri)

# DBAPI - PEP249
# create table
engine.execute('CREATE TABLE "EX1" ('
               'id INTEGER NOT NULL,'
               'name VARCHAR, '
               'PRIMARY KEY (id));')

# insert a row
engine.execute('INSERT INTO "EX1" '
               '(id, name) '
               'VALUES (1,"raw1")')

# select *
result = engine.execute('SELECT * FROM '
                        '"EX1"')

for _r in result:
    print(_r)

# delete *
engine.execute('DELETE from "EX1" where id=1;')
result = engine.execute('SELECT * FROM "EX1"')
print(result.fetchall())
```

3.5.3 Transaction and Connect Object

```
from sqlalchemy import create_engine

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri)

# Create connection
conn = engine.connect()
# Begin transaction
trans = conn.begin()
conn.execute('INSERT INTO "EX1" (name) '
```

(continues on next page)

(continued from previous page)

```
        'VALUES ("Hello")')
trans.commit()
# Close connection
conn.close()
```

3.5.4 Metadata - Generating Database Schema

```
from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import Column
from sqlalchemy import Integer, String

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri)

# Create a metadata instance
metadata = MetaData(engine)
# Declare a table
table = Table('Example', metadata,
              Column('id', Integer, primary_key=True),
              Column('name', String))
# Create all tables
metadata.create_all()
for _t in metadata.tables:
    print("Table: ", _t)
```

3.5.5 Inspect - Get Database Information

```
from sqlalchemy import create_engine
from sqlalchemy import inspect

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri)

inspector = inspect(engine)

# Get table information
print(inspector.get_table_names())

# Get column information
print(inspector.get_columns('EX1'))
```

3.5.6 Reflection - Loading Table from Existing Database

```
from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri)

# Create a MetaData instance
metadata = MetaData()
print(metadata.tables)

# reflect db schema to MetaData
metadata.reflect(bind=engine)
print(metadata.tables)
```

3.5.7 Print Create Table Statement with Indexes (SQL DDL)

```
from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import Column
from sqlalchemy import Integer
from sqlalchemy import String

def metadata_dump(sql, *multiparams, **params):
    print(sql.compile(dialect=engine.dialect))

meta = MetaData()
example_table = Table('Example', meta,
                      Column('id', Integer, primary_key=True),
                      Column('name', String(10), index=True))

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri, strategy='mock', executor=metadata_dump)

meta.create_all(bind=engine, tables=[example_table])
```

output:

```
CREATE TABLE "Example" (
  id INTEGER NOT NULL,
  name VARCHAR(10),
  PRIMARY KEY (id)
)

CREATE INDEX "ix_Example_name" ON "Example" (name)
```


3.5.8 Get Table from MetaData

```
from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri)

# Create MetaData instance
metadata = MetaData(engine).reflect()
print(metadata.tables)

# Get Table
ex_table = metadata.tables['Example']
print(ex_table)
```

3.5.9 Create all Tables Store in “MetaData”

```
from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import Column
from sqlalchemy import Integer, String

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri)
meta = MetaData(engine)

# Register t1, t2 to metadata
t1 = Table('EX1', meta,
           Column('id', Integer, primary_key=True),
           Column('name', String))

t2 = Table('EX2', meta,
           Column('id', Integer, primary_key=True),
           Column('val', Integer))

# Create all tables in meta
meta.create_all()
```

3.5.10 Create Specific Table

```
from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import Column
from sqlalchemy import Integer, String

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri)
```

(continues on next page)

(continued from previous page)

```
meta = MetaData(engine)
t1 = Table('Table_1', meta,
           Column('id', Integer, primary_key=True),
           Column('name', String))
t2 = Table('Table_2', meta,
           Column('id', Integer, primary_key=True),
           Column('val', Integer))
t1.create()
```

3.5.11 Create table with same columns

```
from sqlalchemy import (
    create_engine,
    inspect,
    Column,
    String,
    Integer)

from sqlalchemy.ext.declarative import declarative_base

db_url = "sqlite://"
engine = create_engine(db_url)

Base = declarative_base()

class TemplateTable(object):
    id = Column(Integer, primary_key=True)
    name = Column(String)
    age = Column(Integer)

class DowntownAPeople(TemplateTable, Base):
    __tablename__ = "downtown_a_people"

class DowntownBPeople(TemplateTable, Base):
    __tablename__ = "downtown_b_people"

Base.metadata.create_all(bind=engine)

# check table exists
ins = inspect(engine)
for _t in ins.get_table_names():
    print(_t)
```

3.5.12 Drop a Table

```

from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import inspect
from sqlalchemy import Table
from sqlalchemy import Column, Integer, String
from sqlalchemy.engine.url import URL

db_url = {'drivername': 'postgres',
          'username': 'postgres',
          'password': 'postgres',
          'host': '192.168.99.100',
          'port': 5432}
engine = create_engine(URL(**db_url))
m = MetaData()
table = Table('Test', m,
              Column('id', Integer, primary_key=True),
              Column('key', String, nullable=True),
              Column('val', String))

table.create(engine)
inspector = inspect(engine)
print('Test' in inspector.get_table_names())

table.drop(engine)
inspector = inspect(engine)
print('Test' in inspector.get_table_names())

```

output:

```

$ python sqlalchemy_drop.py
$ True
$ False

```

3.5.13 Some Table Object Operation

```

from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import Column
from sqlalchemy import Integer, String

meta = MetaData()
t = Table('ex_table', meta,
          Column('id', Integer, primary_key=True),
          Column('key', String),
          Column('val', Integer))
# Get Table Name
print(t.name)

# Get Columns

```

(continues on next page)

(continued from previous page)

```

print(t.columns.keys())

# Get Column
c = t.c.key
print(c.name)
# Or
c = t.columns[key]
print(c.name)

# Get Table from Column
print(c.table)

```

3.5.14 SQL Expression Language

```

# Think Column as "ColumnElement"
# Implement via overwrite special function
from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import Column
from sqlalchemy import Integer, String
from sqlalchemy import or_

meta = MetaData()
table = Table('example', meta,
              Column('id', Integer, primary_key=True),
              Column('l_name', String),
              Column('f_name', String))

# sql expression binary object
print(repr(table.c.l_name == 'ed'))
# exhibit sql expression
print(str(table.c.l_name == 'ed'))

print(repr(table.c.f_name != 'ed'))

# comparison operator
print(repr(table.c.id > 3))

# or expression
print((table.c.id > 5) | (table.c.id < 2))
# Equal to
print(or_(table.c.id > 5, table.c.id < 2))

# compare to None produce IS NULL
print(table.c.l_name == None)
# Equal to
print(table.c.l_name.is_(None))

# + means "addition"
print(table.c.id + 5)
# or means "string concatenation"

```

(continues on next page)

(continued from previous page)

```
print(table.c.l_name + "some name")

# in expression
print(table.c.l_name.in_(['a', 'b']))
```

3.5.15 insert() - Create an “INSERT” Statement

```
from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import Column
from sqlalchemy import Integer
from sqlalchemy import String

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri)

# create table
meta = MetaData(engine)
table = Table('user', meta,
              Column('id', Integer, primary_key=True),
              Column('l_name', String),
              Column('f_name', String))
meta.create_all()

# insert data via insert() construct
ins = table.insert().values(
    l_name='Hello',
    f_name='World')
conn = engine.connect()
conn.execute(ins)

# insert multiple data
conn.execute(table.insert(), [
    {'l_name': 'Hi', 'f_name': 'bob'},
    {'l_name': 'yo', 'f_name': 'alice'}])
```

3.5.16 select() - Create a “SELECT” Statement

```
from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import select
from sqlalchemy import or_

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri)
conn = engine.connect()
```

(continues on next page)

(continued from previous page)

```

meta = MetaData(engine).reflect()
table = meta.tables['user']

# select * from 'user'
select_st = select([table]).where(
    table.c.l_name == 'Hello')
res = conn.execute(select_st)
for _row in res:
    print(_row)

# or equal to
select_st = table.select().where(
    table.c.l_name == 'Hello')
res = conn.execute(select_st)
for _row in res:
    print(_row)

# combine with "OR"
select_st = select([
    table.c.l_name,
    table.c.f_name]).where(or_(
    table.c.l_name == 'Hello',
    table.c.l_name == 'Hi'))
res = conn.execute(select_st)
for _row in res:
    print(_row)

# combine with "ORDER_BY"
select_st = select([table]).where(or_(
    table.c.l_name == 'Hello',
    table.c.l_name == 'Hi')).order_by(table.c.f_name)
res = conn.execute(select_st)
for _row in res:
    print(_row)

```

3.5.17 join() - Joined Two Tables via “JOIN” Statement

```

from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import Column
from sqlalchemy import Integer
from sqlalchemy import String
from sqlalchemy import select

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri)

meta = MetaData(engine).reflect()
email_t = Table('email_addr', meta,

```

(continues on next page)

(continued from previous page)

```

        Column('id', Integer, primary_key=True),
        Column('email', String),
        Column('name', String))
meta.create_all()

# get user table
user_t = meta.tables['user']

# insert
conn = engine.connect()
conn.execute(email_t.insert(),[
    {'email':'ker@test', 'name':'Hi'},
    {'email':'yo@test', 'name':'Hello'}])
# join statement
join_obj = user_t.join(email_t,
    email_t.c.name == user_t.c.l_name)
# using select_from
sel_st = select(
    [user_t.c.l_name, email_t.c.email]).select_from(join_obj)
res = conn.execute(sel_st)
for _row in res:
    print(_row)

```

3.5.18 Fastest Bulk Insert in PostgreSQL via “COPY” Statement

```

# This method found here: https://gist.github.com/jsheedy/efa9a69926a754bebf0e9078fd085df6
↪ efa9a69926a754bebf0e9078fd085df6
import io
from datetime import date

from sqlalchemy.engine.url import URL
from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import Column
from sqlalchemy import Integer
from sqlalchemy import String
from sqlalchemy import Date

db_url = {'drivername': 'postgres',
          'username': 'postgres',
          'password': 'postgres',
          'host': '192.168.99.100',
          'port': 5432}
engine = create_engine(URL(**db_url))

# create table
meta = MetaData(engine)
table = Table('userinfo', meta,

```

(continues on next page)

(continued from previous page)

```

    Column('id', Integer, primary_key=True),
    Column('first_name', String),
    Column('age', Integer),
    Column('birth_day', Date),
)
meta.create_all()

# file-like object (tsv format)
datafile = io.StringIO()

# generate rows
for i in range(100):
    line = '\t'.join(
        [
            f'Name {i}',    # first_name
            str(18 + i),    # age
            str(date.today()), # birth_day
        ]
    )
    datafile.write(line + '\n')

# reset file to start
datafile.seek(0)

# bulk insert via `COPY` statement
conn = engine.raw_connection()
with conn.cursor() as cur:
    # https://www.psycopg.org/docs/cursor.html#cursor.copy_from
    cur.copy_from(
        datafile,
        table.name, # table name
        sep='\t',
        columns=('first_name', 'age', 'birth_day'),
    )
conn.commit()

```

3.5.19 Bulk PostgreSQL Insert and Return Inserted IDs

```

from sqlalchemy.engine.url import URL
from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import Column
from sqlalchemy import Integer
from sqlalchemy import String

db_url = {'drivername': 'postgres',
          'username': 'postgres',
          'password': 'postgres',
          'host': '192.168.99.100',

```

(continues on next page)

(continued from previous page)

```

        'port': 5432}
engine = create_engine(URL(**db_url))

# create table
meta = MetaData(engine)
table = Table('userinfo', meta,
              Column('id', Integer, primary_key=True),
              Column('first_name', String),
              Column('age', Integer),
              )
meta.create_all()

# generate rows
data = [{'first_name': f'Name {i}', 'age': 18+i} for i in range(10)]

stmt = table.insert().values(data).returning(table.c.id)
# converted into SQL:
# INSERT INTO userinfo (first_name, age) VALUES
#   %(first_name_m0)s, %(age_m0)s), %(first_name_m1)s, %(age_m1)s),
#   %(first_name_m2)s, %(age_m2)s), %(first_name_m3)s, %(age_m3)s),
#   %(first_name_m4)s, %(age_m4)s), %(first_name_m5)s, %(age_m5)s),
#   %(first_name_m6)s, %(age_m6)s), %(first_name_m7)s, %(age_m7)s),
#   %(first_name_m8)s, %(age_m8)s), %(first_name_m9)s, %(age_m9)s)
# RETURNING userinfo.id
for rowid in engine.execute(stmt).fetchall():
    print(rowid['id'])

```

output:

```

$ python sqlalchemy_bulk.py
1
2
3
4
5
6
7
8
9
10

```

3.5.20 Update Multiple Rows

```

from sqlalchemy.engine.url import URL
from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import Column
from sqlalchemy import Integer
from sqlalchemy import String

```

(continues on next page)

(continued from previous page)

```

from sqlalchemy.sql.expression import bindparam

db_url = {'drivername': 'postgres',
          'username': 'postgres',
          'password': 'postgres',
          'host': '192.168.99.100',
          'port': 5432}
engine = create_engine(URL(**db_url))

# create table
meta = MetaData(engine)
table = Table('userinfo', meta,
              Column('id', Integer, primary_key=True),
              Column('first_name', String),
              Column('birth_year', Integer),
              )
meta.create_all()

# update data
data = [
    {'_id': 1, 'first_name': 'Johnny', 'birth_year': 1975},
    {'_id': 2, 'first_name': 'Jim', 'birth_year': 1973},
    {'_id': 3, 'first_name': 'Kaley', 'birth_year': 1985},
    {'_id': 4, 'first_name': 'Simon', 'birth_year': 1980},
    {'_id': 5, 'first_name': 'Kunal', 'birth_year': 1981},
    {'_id': 6, 'first_name': 'Mayim', 'birth_year': 1975},
    {'_id': 7, 'first_name': 'Melissa', 'birth_year': 1980},
]

stmt = table.update().where(table.c.id == bindparam('_id')).\
    values({
        'first_name': bindparam('first_name'),
        'birth_year': bindparam('birth_year'),
    })
# conveted to SQL:
# UPDATE userinfo SET first_name=%(first_name)s, birth_year=%(birth_year)s WHERE_
↪ userinfo.id = %(id)s

engine.execute(stmt, data)

```

3.5.21 Delete Rows from Table

```

from sqlalchemy import create_engine
from sqlalchemy import MetaData

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri)
conn = engine.connect()

meta = MetaData(engine).reflect()

```

(continues on next page)

(continued from previous page)

```

user_t = meta.tables['user']

# select * from user_t
sel_st = user_t.select()
res = conn.execute(sel_st)
for _row in res:
    print(_row)

# delete l_name == 'Hello'
del_st = user_t.delete().where(
    user_t.c.l_name == 'Hello')
print('----- delete -----')
res = conn.execute(del_st)

# check rows has been delete
sel_st = user_t.select()
res = conn.execute(sel_st)
for _row in res:
    print(_row)

```

3.5.22 Check Table Existing

```

from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Column
from sqlalchemy import Integer, String
from sqlalchemy import inspect
from sqlalchemy.ext.declarative import declarative_base

Modal = declarative_base()
class Example(Modal):
    __tablename__ = "ex_t"
    id = Column(Integer, primary_key=True)
    name = Column(String(20))

db_uri = 'sqlite:///db.sqlite'
engine = create_engine(db_uri)
Modal.metadata.create_all(engine)

# check register table exist to Modal
for _t in Modal.metadata.tables:
    print(_t)

# check all table in database
meta = MetaData(engine).reflect()
for _t in meta.tables:
    print(_t)

# check table names exists via inspect
ins = inspect(engine)

```

(continues on next page)

(continued from previous page)

```
for _t in ins.get_table_names():
    print(_t)
```

3.5.23 Create multiple tables at once

```
from sqlalchemy import create_engine
from sqlalchemy import MetaData
from sqlalchemy import Table
from sqlalchemy import inspect
from sqlalchemy import Column, String, Integer
from sqlalchemy.engine.url import URL

db = {'drivername': 'postgres',
      'username': 'postgres',
      'password': 'postgres',
      'host': '192.168.99.100',
      'port': 5432}

url = URL(**db)
engine = create_engine(url)

metadata = MetaData()
metadata.reflect(bind=engine)

def create_table(name, metadata):
    tables = metadata.tables.keys()
    if name not in tables:
        table = Table(name, metadata,
                      Column('id', Integer, primary_key=True),
                      Column('key', String),
                      Column('val', Integer))
        table.create(engine)

tables = ['table1', 'table2', 'table3']
for _t in tables: create_table(_t, metadata)

inspector = inspect(engine)
print(inspector.get_table_names())
```

output:

```
$ python sqlalchemy_create.py
[u'table1', u'table2', u'table3']
```

3.5.24 Create tables with dynamic columns (Table)

```
from sqlalchemy import create_engine
from sqlalchemy import Column, Integer, String
from sqlalchemy import Table
from sqlalchemy import MetaData
from sqlalchemy import inspect
from sqlalchemy.engine.url import URL

db_url = {'drivername': 'postgres',
          'username': 'postgres',
          'password': 'postgres',
          'host': '192.168.99.100',
          'port': 5432}

engine = create_engine(URL(**db_url))

def create_table(name, *cols):
    meta = MetaData()
    meta.reflect(bind=engine)
    if name in meta.tables: return

    table = Table(name, meta, *cols)
    table.create(engine)

create_table('Table1',
            Column('id', Integer, primary_key=True),
            Column('name', String))
create_table('Table2',
            Column('id', Integer, primary_key=True),
            Column('key', String),
            Column('val', String))

inspector = inspect(engine)
for _t in inspector.get_table_names():
    print(_t)
```

output:

```
$ python sqlalchemy_dynamic.py
Table1
Table2
```

3.5.25 Object Relational add data

```
from datetime import datetime

from sqlalchemy import create_engine
from sqlalchemy import Column, Integer, String, DateTime
from sqlalchemy.orm import sessionmaker
from sqlalchemy.exc import SQLAlchemyError
from sqlalchemy.ext.declarative import declarative_base
from sqlalchemy.engine.url import URL

db_url = {'drivername': 'postgres',
          'username': 'postgres',
          'password': 'postgres',
          'host': '192.168.99.100',
          'port': 5432}
engine = create_engine(URL(**db_url))

Base = declarative_base()

class TestTable(Base):
    __tablename__ = 'Test Table'
    id = Column(Integer, primary_key=True)
    key = Column(String, nullable=False)
    val = Column(String)
    date = Column(DateTime, default=datetime.utcnow)

# create tables
Base.metadata.create_all(bind=engine)

# create session
Session = sessionmaker()
Session.configure(bind=engine)
session = Session()

data = {'a': 5566, 'b': 9527, 'c': 183}
try:
    for _key, _val in data.items():
        row = TestTable(key=_key, val=_val)
        session.add(row)
    session.commit()
except SQLAlchemyError as e:
    print(e)
finally:
    session.close()
```

3.5.26 Object Relational update data

```

from datetime import datetime

from sqlalchemy import create_engine
from sqlalchemy import Column, Integer, String, DateTime
from sqlalchemy.orm import sessionmaker
from sqlalchemy.exc import SQLAlchemyError
from sqlalchemy.ext.declarative import declarative_base
from sqlalchemy.engine.url import URL

db_url = {'drivername': 'postgres',
          'username': 'postgres',
          'password': 'postgres',
          'host': '192.168.99.100',
          'port': 5432}
engine = create_engine(URL(**db_url))
Base = declarative_base()

class TestTable(Base):
    __tablename__ = 'Test Table'
    id = Column(Integer, primary_key=True)
    key = Column(String, nullable=False)
    val = Column(String)
    date = Column(DateTime, default=datetime.utcnow)

# create tables
Base.metadata.create_all(bind=engine)

# create session
Session = sessionmaker()
Session.configure(bind=engine)
session = Session()

try:
    # add row to database
    row = TestTable(key="hello", val="world")
    session.add(row)
    session.commit()

    # update row to database
    row = session.query(TestTable).filter(
        TestTable.key == 'hello').first()
    print('original:', row.key, row.val)
    row.key = "Hello"
    row.val = "World"
    session.commit()

    # check update correct
    row = session.query(TestTable).filter(
        TestTable.key == 'Hello').first()
    print('update:', row.key, row.val)
except SQLAlchemyError as e:

```

(continues on next page)

(continued from previous page)

```

    print(e)
finally:
    session.close()

```

output:

```

$ python sqlalchemy_update.py
original: hello world
update: Hello World

```

3.5.27 Object Relational delete row

```

from datetime import datetime

from sqlalchemy import create_engine
from sqlalchemy import Column, Integer, String, DateTime
from sqlalchemy.orm import sessionmaker
from sqlalchemy.exc import SQLAlchemyError
from sqlalchemy.ext.declarative import declarative_base
from sqlalchemy.engine.url import URL

db_url = {'drivername': 'postgres',
          'username': 'postgres',
          'password': 'postgres',
          'host': '192.168.99.100',
          'port': 5432}
engine = create_engine(URL(**db_url))
Base = declarative_base()

class TestTable(Base):
    __tablename__ = 'Test Table'
    id = Column(Integer, primary_key=True)
    key = Column(String, nullable=False)
    val = Column(String)
    date = Column(DateTime, default=datetime.utcnow)

# create tables
Base.metadata.create_all(bind=engine)

# create session
Session = sessionmaker()
Session.configure(bind=engine)
session = Session()

row = TestTable(key='hello', val='world')
session.add(row)
query = session.query(TestTable).filter(
    TestTable.key=='hello')
print(query.first())

```

(continues on next page)

(continued from previous page)

```

query.delete()
query = session.query(TestTable).filter(
    TestTable.key=='hello')
print(query.all())

```

output:

```

$ python sqlalchemy_delete.py
<__main__.TestTable object at 0x104eb8f50>
[]

```

3.5.28 Object Relational relationship

```

from sqlalchemy import Column, String, Integer, ForeignKey
from sqlalchemy.orm import relationship
from sqlalchemy.ext.declarative import declarative_base

Base = declarative_base()

class User(Base):
    __tablename__ = 'user'
    id = Column(Integer, primary_key=True)
    name = Column(String)
    addresses = relationship("Address", backref="user")

class Address(Base):
    __tablename__ = 'address'
    id = Column(Integer, primary_key=True)
    email = Column(String)
    user_id = Column(Integer, ForeignKey('user.id'))

u1 = User()
a1 = Address()
print(u1.addresses)
print(a1.user)

u1.addresses.append(a1)
print(u1.addresses)
print(a1.user)

```

output:

```

$ python sqlalchemy_relationship.py
[]
None
[<__main__.Address object at 0x10c4edb50>]
<__main__.User object at 0x10c4ed810>

```

3.5.29 Object Relational self association

```
import json

from sqlalchemy import (
    Column,
    Integer,
    String,
    ForeignKey,
    Table)

from sqlalchemy.orm import (
    sessionmaker,
    relationship)

from sqlalchemy.ext.declarative import declarative_base

base = declarative_base()

association = Table("Association", base.metadata,
    Column('left', Integer, ForeignKey('node.id'), primary_key=True),
    Column('right', Integer, ForeignKey('node.id'), primary_key=True))

class Node(base):
    __tablename__ = 'node'
    id = Column(Integer, primary_key=True)
    label = Column(String)
    friends = relationship('Node',
        secondary=association,
        primaryjoin=id==association.c.left,
        secondaryjoin=id==association.c.right,
        backref='left')

    def to_json(self):
        return dict(id=self.id,
            friends=[_.label for _ in self.friends])

nodes = [Node(label='node_{}'.format(_)) for _ in range(0, 3)]
nodes[0].friends.extend([nodes[1], nodes[2]])
nodes[1].friends.append(nodes[2])

print('----> right')
print(json.dumps([_.to_json() for _ in nodes], indent=2))

print('----> left')
print(json.dumps([_n.to_json() for _n in nodes[1].left], indent=2))
```

output:

```
----> right
[
  {
    "friends": [
      "node_1",
```

(continues on next page)

(continued from previous page)

```

        "node_2"
    ],
    "id": null
},
{
    "friends": [
        "node_2"
    ],
    "id": null
},
{
    "friends": [],
    "id": null
}
]
----> left
[
    {
        "friends": [
            "node_1",
            "node_2"
        ],
        "id": null
    }
]

```

3.5.30 Object Relational basic query

```

from datetime import datetime

from sqlalchemy import create_engine
from sqlalchemy import Column, String, Integer, DateTime
from sqlalchemy import or_
from sqlalchemy import desc
from sqlalchemy.orm import sessionmaker
from sqlalchemy.exc import SQLAlchemyError
from sqlalchemy.ext.declarative import declarative_base
from sqlalchemy.engine.url import URL

db_url = {'drivername': 'postgres',
          'username': 'postgres',
          'password': 'postgres',
          'host': '192.168.99.100',
          'port': 5432}

Base = declarative_base()

class User(Base):
    __tablename__ = 'User'
    id = Column(Integer, primary_key=True)

```

(continues on next page)

(continued from previous page)

```

name      = Column(String, nullable=False)
fullname  = Column(String, nullable=False)
birth     = Column(DateTime)

# create tables
engine = create_engine(URL(**db_url))
Base.metadata.create_all(bind=engine)

users = [
    User(name='ed',
          fullname='Ed Jones',
          birth=datetime(1989,7,1)),
    User(name='wendy',
          fullname='Wendy Williams',
          birth=datetime(1983,4,1)),
    User(name='mary',
          fullname='Mary Contrary',
          birth=datetime(1990,1,30)),
    User(name='fred',
          fullname='Fred Flinstone',
          birth=datetime(1977,3,12)),
    User(name='justin',
          fullname="Justin Bieber")]

# create session
Session = sessionmaker()
Session.configure(bind=engine)
session = Session()

# add_all
session.add_all(users)
session.commit()

print("----> order_by(id):")
query = session.query(User).order_by(User.id)
for _row in query.all():
    print(_row.name, _row.fullname, _row.birth)

print("\n----> order_by(desc(id)):")
query = session.query(User).order_by(desc(User.id))
for _row in query.all():
    print(_row.name, _row.fullname, _row.birth)

print("\n----> order_by(date):")
query = session.query(User).order_by(User.birth)
for _row in query.all():
    print(_row.name, _row.fullname, _row.birth)

print("\n----> EQUAL:")
query = session.query(User).filter(User.id == 2)
_row = query.first()
print(_row.name, _row.fullname, _row.birth)

```

(continues on next page)

(continued from previous page)

```

print("\n----> NOT EQUAL:")
query = session.query(User).filter(User.id != 2)
for _row in query.all():
    print(_row.name, _row.fullname, _row.birth)

print("\n----> IN:")
query = session.query(User).filter(User.name.in_(['ed', 'wendy']))
for _row in query.all():
    print(_row.name, _row.fullname, _row.birth)

print("\n----> NOT IN:")
query = session.query(User).filter(~User.name.in_(['ed', 'wendy']))
for _row in query.all():
    print(_row.name, _row.fullname, _row.birth)

print("\n----> AND:")
query = session.query(User).filter(
    User.name=='ed', User.fullname=='Ed Jones')
_row = query.first()
print(_row.name, _row.fullname, _row.birth)

print("\n----> OR:")
query = session.query(User).filter(
    or_(User.name=='ed', User.name=='wendy'))
for _row in query.all():
    print(_row.name, _row.fullname, _row.birth)

print("\n----> NULL:")
query = session.query(User).filter(User.birth == None)
for _row in query.all():
    print(_row.name, _row.fullname)

print("\n----> NOT NULL:")
query = session.query(User).filter(User.birth != None)
for _row in query.all():
    print(_row.name, _row.fullname)

print("\n----> LIKE")
query = session.query(User).filter(User.name.like('%ed%'))
for _row in query.all():
    print(_row.name, _row.fullname)

```

output:

```

----> order_by(id):
ed Ed Jones 1989-07-01 00:00:00
wendy Wendy Williams 1983-04-01 00:00:00
mary Mary Contrary 1990-01-30 00:00:00
fred Fred Flinstone 1977-03-12 00:00:00
justin Justin Bieber None

```

(continues on next page)

(continued from previous page)

```
----> order_by(desc(id)):  
justin Justin Bieber None  
fred Fred Flinstone 1977-03-12 00:00:00  
mary Mary Contrary 1990-01-30 00:00:00  
wendy Wendy Williams 1983-04-01 00:00:00  
ed Ed Jones 1989-07-01 00:00:00  
  
----> order_by(date):  
fred Fred Flinstone 1977-03-12 00:00:00  
wendy Wendy Williams 1983-04-01 00:00:00  
ed Ed Jones 1989-07-01 00:00:00  
mary Mary Contrary 1990-01-30 00:00:00  
justin Justin Bieber None  
  
----> EQUAL:  
wendy Wendy Williams 1983-04-01 00:00:00  
  
----> NOT EQUAL:  
ed Ed Jones 1989-07-01 00:00:00  
mary Mary Contrary 1990-01-30 00:00:00  
fred Fred Flinstone 1977-03-12 00:00:00  
justin Justin Bieber None  
  
----> IN:  
ed Ed Jones 1989-07-01 00:00:00  
wendy Wendy Williams 1983-04-01 00:00:00  
  
----> NOT IN:  
mary Mary Contrary 1990-01-30 00:00:00  
fred Fred Flinstone 1977-03-12 00:00:00  
justin Justin Bieber None  
  
----> AND:  
ed Ed Jones 1989-07-01 00:00:00  
  
----> OR:  
ed Ed Jones 1989-07-01 00:00:00  
wendy Wendy Williams 1983-04-01 00:00:00  
  
----> NULL:  
justin Justin Bieber  
  
----> NOT NULL:  
ed Ed Jones  
wendy Wendy Williams  
mary Mary Contrary  
fred Fred Flinstone  
  
----> LIKE  
ed Ed Jones  
fred Fred Flinstone
```

3.5.31 mapper: Map Table to class

```

from sqlalchemy import (
    create_engine,
    Table,
    MetaData,
    Column,
    Integer,
    String,
    ForeignKey)

from sqlalchemy.orm import (
    mapper,
    relationship,
    sessionmaker)

# classical mapping: map "table" to "class"
db_url = 'sqlite://'
engine = create_engine(db_url)

meta = MetaData(bind=engine)

user = Table('User', meta,
             Column('id', Integer, primary_key=True),
             Column('name', String),
             Column('fullname', String),
             Column('password', String))

addr = Table('Address', meta,
             Column('id', Integer, primary_key=True),
             Column('email', String),
             Column('user_id', Integer, ForeignKey('User.id'))))

# map table to class
class User(object):
    def __init__(self, name, fullname, password):
        self.name = name
        self.fullname = fullname
        self.password = password

class Address(object):
    def __init__(self, email):
        self.email = email

mapper(User, user, properties={
    'addresses': relationship(Address, backref='user')})
mapper(Address, addr)

# create table
meta.create_all()

# create session
Session = sessionmaker()

```

(continues on next page)

(continued from previous page)

```
Session.configure(bind=engine)
session = Session()

u = User(name='Hello', fullname='HelloWorld', password='ker')
a = Address(email='hello@hello.com')
u.addresses.append(a)
try:
    session.add(u)
    session.commit()

    # query result
    u = session.query(User).filter(User.name == 'Hello').first()
    print(u.name, u.fullname, u.password)

finally:
    session.close()
```

output:

```
$ python map_table_class.py
Hello HelloWorld ker
```

3.5.32 Get table dynamically

```
from sqlalchemy import (
    create_engine,
    MetaData,
    Table,
    inspect,
    Column,
    String,
    Integer)

from sqlalchemy.orm import (
    mapper,
    scoped_session,
    sessionmaker)

db_url = "sqlite://"
engine = create_engine(db_url)
metadata = MetaData(engine)

class TableTemp(object):
    def __init__(self, name):
        self.name = name

def get_table(name):
    if name in metadata.tables:
        table = metadata.tables[name]
    else:
```

(continues on next page)

(continued from previous page)

```

        table = Table(name, metadata,
                      Column('id', Integer, primary_key=True),
                      Column('name', String))
        table.create(engine)

    cls = type(name.title(), (TableTemp,), {})
    mapper(cls, table)
    return cls

# get table first times
t = get_table('Hello')

# get table secone times
t = get_table('Hello')

Session = scoped_session(sessionmaker(bind=engine))
try:
    Session.add(t(name='foo'))
    Session.add(t(name='bar'))
    for _ in Session.query(t).all():
        print(_.name)
except Exception as e:
    Session.rollback()
finally:
    Session.close()

```

output:

```

$ python get_table.py
foo
bar

```

3.5.33 Object Relational join two tables

```

from sqlalchemy import create_engine
from sqlalchemy import Column, Integer, String, ForeignKey
from sqlalchemy.orm import relationship
from sqlalchemy.engine.url import URL
from sqlalchemy.orm import sessionmaker
from sqlalchemy.ext.declarative import declarative_base

Base = declarative_base()

class User(Base):
    __tablename__ = 'user'
    id = Column(Integer, primary_key=True)
    name = Column(String)
    addresses = relationship("Address", backref="user")

class Address(Base):

```

(continues on next page)

(continued from previous page)

```

__tablename__ = 'address'
id = Column(Integer, primary_key=True)
email = Column(String)
user_id = Column(Integer, ForeignKey('user.id'))

db_url = {'drivername': 'postgres',
          'username': 'postgres',
          'password': 'postgres',
          'host': '192.168.99.100',
          'port': 5432}

# create engine
engine = create_engine(URL(**db_url))

# create tables
Base.metadata.create_all(bind=engine)

# create session
Session = sessionmaker()
Session.configure(bind=engine)
session = Session()

user = User(name='user1')
mail1 = Address(email='user1@foo.com')
mail2 = Address(email='user1@bar.com')
user.addresses.extend([mail1, mail2])

session.add(user)
session.add_all([mail1, mail2])
session.commit()

query = session.query(Address, User).join(User)
for _a, _u in query.all():
    print(_u.name, _a.email)

```

output:

```

$ python sqlalchemy_join.py
user1 user1@foo.com
user1 user1@bar.com

```

3.5.34 join on relationship and group_by count

```

from sqlalchemy import (
    create_engine,
    Column,
    String,
    Integer,
    ForeignKey,
    func)

```

(continues on next page)

(continued from previous page)

```

from sqlalchemy.orm import (
    relationship,
    sessionmaker,
    scoped_session)

from sqlalchemy.ext.declarative import declarative_base

db_url = 'sqlite:///'
engine = create_engine(db_url)

Base = declarative_base()

class Parent(Base):
    __tablename__ = 'parent'
    id = Column(Integer, primary_key=True)
    name = Column(String)
    children = relationship('Child', back_populates='parent')

class Child(Base):
    __tablename__ = 'child'
    id = Column(Integer, primary_key=True)
    name = Column(String)
    parent_id = Column(Integer, ForeignKey('parent.id'))
    parent = relationship('Parent', back_populates='children')

Base.metadata.create_all(bind=engine)
Session = scoped_session(sessionmaker(bind=engine))

p1 = Parent(name="Alice")
p2 = Parent(name="Bob")

c1 = Child(name="foo")
c2 = Child(name="bar")
c3 = Child(name="ker")
c4 = Child(name="cat")

p1.children.extend([c1, c2, c3])
p2.children.append(c4)

try:
    Session.add(p1)
    Session.add(p2)
    Session.commit()

    # count number of children
    q = Session.query(Parent, func.count(Child.id))\
        .join(Child)\
        .group_by(Parent.id)

    # print result
    for _p, _c in q.all():

```

(continues on next page)

(continued from previous page)

```

        print('parent: {}, num_child: {}'.format(_p.name, _c))
    finally:
        Session.remove()

```

output:

```

$ python join_group_by.py
parent: Alice, num_child: 3
parent: Bob, num_child: 1

```

3.5.35 Create tables with dynamic columns (ORM)

```

from sqlalchemy import create_engine
from sqlalchemy import Column, Integer, String
from sqlalchemy import inspect
from sqlalchemy.engine.url import URL
from sqlalchemy.ext.declarative import declarative_base

db_url = {'drivername': 'postgres',
          'username': 'postgres',
          'password': 'postgres',
          'host': '192.168.99.100',
          'port': 5432}

engine = create_engine(URL(**db_url))
Base = declarative_base()

def create_table(name, cols):
    Base.metadata.reflect(engine)
    if name in Base.metadata.tables: return

    table = type(name, (Base,), cols)
    table.__table__.create(bind=engine)

create_table('Table1', {
    '__tablename__': 'Table1',
    'id': Column(Integer, primary_key=True),
    'name': Column(String)})

create_table('Table2', {
    '__tablename__': 'Table2',
    'id': Column(Integer, primary_key=True),
    'key': Column(String),
    'val': Column(String)})

inspector = inspect(engine)
for _t in inspector.get_table_names():
    print(_t)

```

output:

```
$ python sqlalchemy_dynamic_orm.py
Table1
Table2
```

3.5.36 Close database connection

```
from sqlalchemy import (
    create_engine,
    event,
    Column,
    Integer)

from sqlalchemy.orm import sessionmaker
from sqlalchemy.ext.declarative import declarative_base

engine = create_engine('sqlite://')
base = declarative_base()

@event.listens_for(engine, 'engine_disposed')
def receive_engine_disposed(engine):
    print("engine dispose")

class Table(base):
    __tablename__ = 'example table'
    id = Column(Integer, primary_key=True)

base.metadata.create_all(bind=engine)
session = sessionmaker(bind=engine)()

try:
    try:
        row = Table()
        session.add(row)
    except Exception as e:
        session.rollback()
        raise
    finally:
        session.close()
finally:
    engine.dispose()
```

output:

```
$ python db_dispose.py
engine dispose
```

Warning: Be careful. Close *session* does not mean close database connection. SQLAlchemy *session* generally represents the *transactions*, not connections.

3.5.37 Cannot use the object after close the session

```
from __future__ import print_function

from sqlalchemy import (
    create_engine,
    Column,
    String,
    Integer)

from sqlalchemy.orm import sessionmaker
from sqlalchemy.ext.declarative import declarative_base

url = 'sqlite://'
engine = create_engine(url)
base = declarative_base()

class Table(base):
    __tablename__ = 'table'
    id = Column(Integer, primary_key=True)
    key = Column(String)
    val = Column(String)

base.metadata.create_all(bind=engine)
session = sessionmaker(bind=engine)()

try:
    t = Table(key="key", val="val")
    try:
        print(t.key, t.val)
        session.add(t)
        session.commit()
    except Exception as e:
        print(e)
        session.rollback()
    finally:
        session.close()

    print(t.key, t.val) # exception raise from here
except Exception as e:
    print("Cannot use the object after close the session")
finally:
    engine.dispose()
```

output:

```
$ python sql.py
key val
Cannot use the object after close the session
```

3.5.38 Hooks

```
from sqlalchemy import Column, String, Integer
from sqlalchemy import create_engine
from sqlalchemy import event
from sqlalchemy.orm import sessionmaker
from sqlalchemy.orm import scoped_session
from sqlalchemy.ext.declarative import declarative_base
```

```
Base = declarative_base()
```

```
class User(Base):
    __tablename__ = "user"
    id = Column(Integer, primary_key=True)
    name = Column(String)
    age = Column(Integer)
```

```
url = "sqlite:///memory:"
engine = create_engine(url)
Base.metadata.create_all(bind=engine)
Session = sessionmaker(bind=engine)
```

```
@event.listens_for(User, "before_insert")
def before_insert(mapper, connection, user):
    print(f"before insert: {user.name}")
```

```
@event.listens_for(User, "after_insert")
def after_insert(mapper, connection, user):
    print(f"after insert: {user.name}")
```

```
try:
    session = scoped_session(Session)
    user = User(name="bob", age=18)
    session.add(user)
    session.commit()
except SQLAlchemyError as e:
    session.rollback()
finally:
    session.close()
```

3.6 Security

Table of Contents

- *Security*
 - *Simple https server*
 - *Generate a SSH key pair*
 - *Get certificate information*
 - *Generate a self-signed certificate*
 - *Prepare a Certificate Signing Request (csr)*
 - *Generate RSA keyfile without passphrase*
 - *Sign a file by a given private key*
 - *Verify a file from a signed digest*
 - *Simple RSA encrypt via pem file*
 - *Simple RSA encrypt via RSA module*
 - *Simple RSA decrypt via pem file*
 - *Simple RSA encrypt with OAEP*
 - *Simple RSA decrypt with OAEP*
 - *Using DSA to proof of identity*
 - *Using AES CBC mode encrypt a file*
 - *Using AES CBC mode decrypt a file*
 - *AES CBC mode encrypt via password (using cryptography)*
 - *AES CBC mode decrypt via password (using cryptography)*
 - *AES CBC mode encrypt via password (using pycrypto)*
 - *AES CBC mode decrypt via password (using pycrypto)*
 - *Ephemeral Diffie Hellman Key Exchange via cryptography*
 - *Calculate DH shared key manually via cryptography*
 - *Calculate DH shared key from (p, g, pubkey)*

3.6.1 Simple https server

```
# python2

>>> import BaseHTTPServer, SimpleHTTPServer
>>> import ssl
>>> host, port = 'localhost', 5566
>>> handler = SimpleHTTPServer.SimpleHTTPRequestHandler
>>> httpd = BaseHTTPServer.HTTPServer((host, port), handler)
```

(continues on next page)

(continued from previous page)

```

>>> httpd.socket = ssl.wrap_socket(httpd.socket,
...                               certfile='./cert.crt',
...                               keyfile='./cert.key',
...                               server_side=True)
>>> httpd.serve_forever()

# python3

>>> from http import server
>>> handler = server.SimpleHTTPRequestHandler
>>> import ssl
>>> host, port = 'localhost', 5566
>>> httpd = server.HTTPServer((host, port), handler)
>>> httpd.socket = ssl.wrap_socket(httpd.socket,
...                               certfile='./cert.crt',
...                               keyfile='./cert.key',
...                               server_side=True)
...
>>> httpd.serve_forever()

```

3.6.2 Generate a SSH key pair

```

from cryptography.hazmat.primitives import serialization
from cryptography.hazmat.primitives.asymmetric import rsa
from cryptography.hazmat.backends import default_backend

key = rsa.generate_private_key(
    backend=default_backend(),
    public_exponent=65537,
    key_size=2048
)
private_key = key.private_bytes(
    serialization.Encoding.PEM,
    serialization.PrivateFormat.PKCS8,
    serialization.NoEncryption(),
)
public_key = key.public_key().public_bytes(
    serialization.Encoding.OpenSSH,
    serialization.PublicFormat.OpenSSH
)

with open('id_rsa', 'wb') as f, open('id_rsa.pub', 'wb') as g:
    f.write(private_key)
    g.write(public_key)

```

3.6.3 Get certificate information

```

from cryptography import x509
from cryptography.hazmat.backends import default_backend

backend = default_backend()
with open('./cert.crt', 'rb') as f:
    crt_data = f.read()
    cert = x509.load_pem_x509_certificate(crt_data, backend)

class Certificate:

    _fields = ['country_name',
               'state_or_province_name',
               'locality_name',
               'organization_name',
               'organizational_unit_name',
               'common_name',
               'email_address']

    def __init__(self, cert):
        assert isinstance(cert, x509.Certificate)
        self._cert = cert
        for attr in self._fields:
            oid = getattr(x509, 'OID_' + attr.upper())
            subject = cert.subject
            info = subject.get_attributes_for_oid(oid)
            setattr(self, attr, info)

cert = Certificate(cert)
for attr in cert._fields:
    for info in getattr(cert, attr):
        print("{}: {}".format(info._oid._name, info._value))

```

output:

```

$ genrsa -out cert.key
Generating RSA private key, 1024 bit long modulus
.....+++++
...+++++
e is 65537 (0x10001)
$ openssl req -x509 -new -nodes \
> -key cert.key -days 365 \
> -out cert.crt
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Country Name (2 letter code) [AU]:TW

```

(continues on next page)

(continued from previous page)

```

State or Province Name (full name) [Some-State]:Taiwan
Locality Name (eg, city) []:Taipei
Organization Name (eg, company) [Internet Widgits Pty Ltd]:personal
Organizational Unit Name (eg, section) []:personal
Common Name (e.g. server FQDN or YOUR name) []:localhost
Email Address []:test@example.com
$ python3 cert.py
countryName: TW
stateOrProvinceName: Taiwan
localityName: Taipei
organizationName: personal
organizationalUnitName: personal
commonName: localhost
emailAddress: test@example.com

```

3.6.4 Generate a self-signed certificate

```

from __future__ import print_function, unicode_literals

from datetime import datetime, timedelta
from OpenSSL import crypto

# load private key
ftype = crypto.FILETYPE_PEM
with open('key.pem', 'rb') as f: k = f.read()
k = crypto.load_privatekey(ftype, k)

now = datetime.now()
expire = now + timedelta(days=365)

# country (countryName, C)
# state or province name (stateOrProvinceName, ST)
# locality (locality, L)
# organization (organizationName, O)
# organizational unit (organizationalUnitName, OU)
# common name (commonName, CN)

cert = crypto.X509()
cert.get_subject().C = "TW"
cert.get_subject().ST = "Taiwan"
cert.get_subject().L = "Taipei"
cert.get_subject().O = "pysheet"
cert.get_subject().OU = "cheat sheet"
cert.get_subject().CN = "pythonsheets.com"
cert.set_serial_number(1000)
cert.set_notBefore(now.strftime("%Y%m%d%H%M%S").encode())
cert.set_notAfter(expire.strftime("%Y%m%d%H%M%S").encode())
cert.set_issuer(cert.get_subject())
cert.set_pubkey(k)
cert.sign(k, 'sha1')

```

(continues on next page)

(continued from previous page)

```
with open('cert.pem', "wb") as f:
    f.write(crypto.dump_certificate(ftype, cert))
```

output:

```
$ openssl genrsa -out key.pem 2048
Generating RSA private key, 2048 bit long modulus
.....+++
.....+++
e is 65537 (0x10001)
$ python3 x509.py
$ openssl x509 -subject -issuer -noout -in cert.pem
subject= /C=TW/ST=Taiwan/L=Taipei/O=pysheet/OU=cheat sheet/CN=pythonsheets.com
issuer= /C=TW/ST=Taiwan/L=Taipei/O=pysheet/OU=cheat sheet/CN=pythonsheets.com
```

3.6.5 Prepare a Certificate Signing Request (csr)

```
from __future__ import print_function, unicode_literals

from OpenSSL import crypto

# load private key
ftype = crypto.FILETYPE_PEM
with open('key.pem', 'rb') as f: key = f.read()
key = crypto.load_privatekey(ftype, key)
req = crypto.X509Req()

alt_name = [ b"DNS:www.pythonsheets.com",
              b"DNS:doc.pythonsheets.com" ]
key_usage = [ b"Digital Signature",
              b"Non Repudiation",
              b"Key Encipherment" ]

# country (countryName, C)
# state or province name (stateOrProvinceName, ST)
# locality (locality, L)
# organization (organizationName, O)
# organizational unit (organizationalUnitName, OU)
# common name (commonName, CN)

req.get_subject().C = "TW"
req.get_subject().ST = "Taiwan"
req.get_subject().L = "Taipei"
req.get_subject().O = "pysheet"
req.get_subject().OU = "cheat sheet"
req.get_subject().CN = "pythonsheets.com"
req.add_extensions([
    crypto.X509Extension( b"basicConstraints",
                          False,
```

(continues on next page)

(continued from previous page)

```

        b"CA:FALSE"),
    crypto.X509Extension( b"keyUsage",
                          False,
                          b", ".join(key_usage)),
    crypto.X509Extension( b"subjectAltName",
                          False,
                          b", ".join(alt_name))
])

req.set_pubkey(key)
req.sign(key, "sha256")

csr = crypto.dump_certificate_request(ftype, req)
with open("cert.csr", 'wb') as f: f.write(csr)

```

output:

```

# create a root ca
$ openssl genrsa -out ca-key.pem 2048
Generating RSA private key, 2048 bit long modulus
.....+++
.....+++
e is 65537 (0x10001)
$ openssl req -x509 -new -nodes -key ca-key.pem \
> -days 10000 -out ca.pem -subj "/CN=root-ca"

# prepare a csr
$ openssl genrsa -out key.pem 2048
Generating RSA private key, 2048 bit long modulus
.....+++
.....+++
e is 65537 (0x10001)
$ python3 x509.py

# prepare openssl.cnf
cat <<EOF > openssl.cnf
> [req]
> req_extensions = v3_req
> distinguished_name = req_distinguished_name
> [req_distinguished_name]
> [ v3_req ]
> basicConstraints = CA:FALSE
> keyUsage = nonRepudiation, digitalSignature, keyEncipherment
> subjectAltName = @alt_names
> [alt_names]
> DNS.1 = www.pythonsheets.com
> DNS.2 = doc.pythonsheets.com
> EOF

# sign a csr
$ openssl x509 -req -in cert.csr -CA ca.pem \
> -CAkey ca-key.pem -CAcreateserial -out cert.pem \

```

(continues on next page)

(continued from previous page)

```
> -days 365 -extensions v3_req -extfile openssl.cnf
Signature ok
subject=/C=TW/ST=Taiwan/L=Taipei/O=pysheet/OU=cheat sheet/CN=pythonsheets.com
Getting CA Private Key

# check
$ openssl x509 -in cert.pem -text -noout
```

3.6.6 Generate RSA keyfile without passphrase

```
# $ openssl genrsa cert.key 2048

>>> from cryptography.hazmat.backends import default_backend
>>> from cryptography.hazmat.primitives import serialization
>>> from cryptography.hazmat.primitives.asymmetric import rsa
>>> key = rsa.generate_private_key(
...     public_exponent=65537,
...     key_size=2048,
...     backend=default_backend())
...
>>> with open('cert.key', 'wb') as f:
...     f.write(key.private_bytes(
...         encoding=serialization.Encoding.PEM,
...         format=serialization.PrivateFormat.TraditionalOpenSSL,
...         encryption_algorithm=serialization.NoEncryption()))
```

3.6.7 Sign a file by a given private key

```
from __future__ import print_function, unicode_literals

from Crypto.PublicKey import RSA
from Crypto.Signature import PKCS1_v1_5
from Crypto.Hash import SHA256

def signer(privkey, data):
    rsakey = RSA.importKey(privkey)
    signer = PKCS1_v1_5.new(rsakey)
    digest = SHA256.new()
    digest.update(data)
    return signer.sign(digest)

with open('private.key', 'rb') as f: key = f.read()
with open('foo.tgz', 'rb') as f: data = f.read()

sign = signer(key, data)
with open('foo.tgz.sha256', 'wb') as f: f.write(sign)
```

output:

```
# generate public & private key
$ openssl genrsa -out private.key 2048
$ openssl rsa -in private.key -pubout -out public.key

$ python3 sign.py
$ openssl dgst -sha256 -verify public.key -signature foo.tgz.sha256 foo.tgz
Verified OK
```

3.6.8 Verify a file from a signed digest

```
from __future__ import print_function, unicode_literals

import sys

from Crypto.PublicKey import RSA
from Crypto.Signature import PKCS1_v1_5
from Crypto.Hash import SHA256

def verifier(pubkey, sig, data):
    rsakey = RSA.importKey(key)
    signer = PKCS1_v1_5.new(rsakey)
    digest = SHA256.new()

    digest.update(data)
    return signer.verify(digest, sig)

with open("public.key", 'rb') as f: key = f.read()
with open("foo.tgz.sha256", 'rb') as f: sig = f.read()
with open("foo.tgz", 'rb') as f: data = f.read()

if verifier(key, sig, data):
    print("Verified OK")
else:
    print("Verification Failure")
```

output:

```
# generate public & private key
$ openssl genrsa -out private.key 2048
$ openssl rsa -in private.key -pubout -out public.key

# do verification
$ cat /dev/urandom | head -c 512 | base64 > foo.txt
$ tar -zcf foo.tgz foo.txt
$ openssl dgst -sha256 -sign private.key -out foo.tgz.sha256 foo.tgz
$ python3 verify.py
Verified OK

# do verification via openssl
$ openssl dgst -sha256 -verify public.key -signature foo.tgz.sha256 foo.tgz
```

(continues on next page)

(continued from previous page)

Verified OK

3.6.9 Simple RSA encrypt via pem file

```

from __future__ import print_function, unicode_literals

import base64
import sys

from Crypto.PublicKey import RSA
from Crypto.Cipher import PKCS1_v1_5

key_text = sys.stdin.read()

# import key via rsa module
pubkey = RSA.importKey(key_text)

# create a cipher via PKCS1.5
cipher = PKCS1_v1_5.new(pubkey)

# encrypt
cipher_text = cipher.encrypt(b"Hello RSA!")

# do base64 encode
cipher_text = base64.b64encode(cipher_text)
print(cipher_text.decode('utf-8'))

```

output:

```

$ openssl genrsa -out private.key 2048
$ openssl rsa -in private.key -pubout -out public.key
$ cat public.key
> python3 rsa.py
> openssl base64 -d -A
> openssl rsautl -decrypt -inkey private.key
Hello RSA!

```

3.6.10 Simple RSA encrypt via RSA module

```

from __future__ import print_function, unicode_literals

import base64
import sys

from Crypto.PublicKey import RSA
from Crypto.Cipher import PKCS1_v1_5
from Crypto.PublicKey.RSA import construct

# prepare public key

```

(continues on next page)

(continued from previous page)

```

e = int('10001', 16)
n = int(sys.stdin.read(), 16)
pubkey = construct((n, e))

# create a cipher via PKCS1.5
cipher = PKCS1_v1_5.new(pubkey)

# encrypt
cipher_text = cipher.encrypt(b"Hello RSA!")

# do base64 encode
cipher_text = base64.b64encode(cipher_text)
print(cipher_text.decode('utf-8'))

```

output:

```

$ openssl genrsa -out private.key 2048
$ openssl rsa -in private.key -pubout -out public.key
$ # check (n, e)
$ openssl rsa -pubin -inform PEM -text -noout < public.key
Public-Key: (2048 bit)
Modulus:
    00:93:d5:58:0c:18:cf:91:f0:74:af:1b:40:09:73:
    0c:d8:13:23:6c:44:60:0d:83:71:e6:f9:61:85:e5:
    b2:d0:8a:73:5c:02:02:51:9a:4f:a7:ab:05:d5:74:
    ff:4d:88:3d:e2:91:b8:b0:9f:7e:a9:a3:b2:3c:99:
    1c:9a:42:4d:ac:2f:6a:e7:eb:0f:a7:e0:a5:81:e5:
    98:49:49:d5:15:3d:53:42:12:08:db:b0:e7:66:2d:
    71:5b:ea:55:4e:2d:9b:40:79:f8:7d:6e:5d:f4:a7:
    d8:13:cb:13:91:c9:ac:5b:55:62:70:44:25:50:ca:
    94:de:78:5d:97:e8:a9:33:66:4f:90:10:00:62:21:
    b6:60:52:65:76:bd:a3:3b:cf:2a:db:3f:66:5f:0d:
    a3:35:ff:29:34:26:6d:63:a2:a6:77:96:5a:84:c7:
    6a:0c:4f:48:52:70:11:8f:85:11:a0:78:f8:60:4b:
    5d:d8:4b:b2:64:e5:ec:99:72:c5:a8:1b:ab:5c:09:
    e1:80:70:91:06:22:ba:97:33:56:0b:65:d8:f3:35:
    66:f8:f9:ea:b9:84:64:8e:3c:14:f7:3d:1f:2c:67:
    ce:64:cf:f9:c5:16:6b:03:a1:7a:c7:fa:4c:38:56:
    ee:e0:4d:5f:ec:46:7e:1f:08:7c:e6:45:a1:fc:17:
    1f:91
Exponent: 65537 (0x10001)
$ openssl rsa -pubin -in public.key -modulus -noout |\
> cut -d'=' -f 2 |\
> python3 rsa.py |\
> openssl base64 -d -A |\
> openssl rsautl -decrypt -inkey private.key
Hello RSA!

```

3.6.11 Simple RSA decrypt via pem file

```
from __future__ import print_function, unicode_literals

import base64
import sys

from Crypto.PublicKey import RSA
from Crypto.Cipher import PKCS1_v1_5

# read key file
with open('private.key') as f: key_text = f.read()

# create a private key object
privkey = RSA.importKey(key_text)

# create a cipher object
cipher = PKCS1_v1_5.new(privkey)

# decode base64
cipher_text = base64.b64decode(sys.stdin.read())

# decrypt
plain_text = cipher.decrypt(cipher_text, None)
print(plain_text.decode('utf-8').strip())
```

output:

```
$ openssl genrsa -out private.key 2048
$ openssl rsa -in private.key -pubout -out public.key
$ echo "Hello openssl RSA encrypt" | \
> openssl rsautl -encrypt -pubin -inkey public.key | \
> openssl base64 -e -A | \
> python3 rsa.py
Hello openssl RSA encrypt
```

3.6.12 Simple RSA encrypt with OAEP

```
from __future__ import print_function, unicode_literals

import base64
import sys

from Crypto.PublicKey import RSA
from Crypto.Cipher import PKCS1_OAEP

# read key file
key_text = sys.stdin.read()

# create a public key object
pubkey = RSA.importKey(key_text)
```

(continues on next page)

(continued from previous page)

```
# create a cipher object
cipher = PKCS1_OAEP.new(pubkey)

# encrypt plain text
cipher_text = cipher.encrypt(b"Hello RSA OAEP!")

# encode via base64
cipher_text = base64.b64encode(cipher_text)
print(cipher_text.decode('utf-8'))
```

output:

```
$ openssl genrsa -out private.key 2048
$ openssl rsa -in private.key -pubout -out public.key
$ cat public.key      | \
> python3 rsa.py      | \
> openssl base64 -d -A | \
> openssl rsautl -decrypt -oaep -inkey private.key
Hello RSA OAEP!
```

3.6.13 Simple RSA decrypt with OAEP

```
from __future__ import print_function, unicode_literals

import base64
import sys

from Crypto.PublicKey import RSA
from Crypto.Cipher import PKCS1_OAEP

# read key file
with open('private.key') as f: key_text = f.read()

# create a private key object
privkey = RSA.importKey(key_text)

# create a cipher object
cipher = PKCS1_OAEP.new(privkey)

# decode base64
cipher_text = base64.b64decode(sys.stdin.read())

# decrypt
plain_text = cipher.decrypt(cipher_text)
print(plain_text.decode('utf-8').strip())
```

output:

```
$ openssl genrsa -out private.key 2048
$ openssl rsa -in private.key -pubout -out public.key
```

(continues on next page)

(continued from previous page)

```
$ echo "Hello RSA encrypt via OAEP"
> openssl rsautl -encrypt -pubin -oaep -inkey public.key
> openssl base64 -e -A
> python3 rsa.py
Hello RSA encrypt via OAEP
```

3.6.14 Using DSA to proof of identity

```
import socket

from cryptography.exceptions import InvalidSignature
from cryptography.hazmat.backends import default_backend
from cryptography.hazmat.primitives import hashes
from cryptography.hazmat.primitives.asymmetric import dsa

alice, bob = socket.socketpair()

def gen_dsa_key():
    private_key = dsa.generate_private_key(
        key_size=2048, backend=default_backend())
    return private_key, private_key.public_key()

def sign_data(data, private_key):
    signature = private_key.sign(data, hashes.SHA256())
    return signature

def verify_data(data, signature, public_key):
    try:
        public_key.verify(signature, data, hashes.SHA256())
    except InvalidSignature:
        print("recv msg: {} not trust!".format(data))
    else:
        print("check msg: {} success!".format(data))

# generate alice private & public key
alice_private_key, alice_public_key = gen_dsa_key()

# alice send message to bob, then bob recv
alice_msg = b"Hello Bob"
b = alice.send(alice_msg)
bob_recv_msg = bob.recv(1024)

# alice send signature to bob, then bob recv
signature = sign_data(alice_msg, alice_private_key)
b = alice.send(signature)
bob_recv_signature = bob.recv(1024)
```

(continues on next page)

(continued from previous page)

```
# bob check message recv from alice
verify_data(bob_recv_msg, bob_recv_signature, alice_public_key)

# attacker modify the msg will make the msg check fail
verify_data(b"I'm attacker!", bob_recv_signature, alice_public_key)
```

output:

```
$ python3 test_dsa.py
check msg: b'Hello Bob' success!
recv msg: b'I'm attacker!' not trust!
```

3.6.15 Using AES CBC mode encrypt a file

```
from __future__ import print_function, unicode_literals

import struct
import sys
import os

from cryptography.hazmat.primitives import padding
from cryptography.hazmat.backends import default_backend
from cryptography.hazmat.primitives.ciphers import (
    Cipher,
    algorithms,
    modes)

backend = default_backend()
key = os.urandom(32)
iv = os.urandom(16)

def encrypt(ptext):
    pad = padding.PKCS7(128).padder()
    ptext = pad.update(ptext) + pad.finalize()

    alg = algorithms.AES(key)
    mode = modes.CBC(iv)
    cipher = Cipher(alg, mode, backend=backend)
    encryptor = cipher.encryptor()
    ctext = encryptor.update(ptext) + encryptor.finalize()

    return ctext

print("key: {}".format(key.hex()))
print("iv: {}".format(iv.hex()))

if len(sys.argv) != 3:
    raise Exception("usage: cmd [file] [enc file]")

# read plain text from file
```

(continues on next page)

(continued from previous page)

```

with open(sys.argv[1], 'rb') as f:
    plaintext = f.read()

# encrypt file
ciphertext = encrypt(plaintext)
with open(sys.argv[2], 'wb') as f:
    f.write(ciphertext)

```

output:

```

$ echo "Encrypt file via AES-CBC" > test.txt
$ python3 aes.py test.txt test.enc
key: f239d9609e3f318b7afda7e4bb8db5b8734f504cf67f55e45dfe75f90d24fefc
iv: 8d6383b469f100d25293fb244ccb951e
$ openssl aes-256-cbc -d -in test.enc -out secrets.txt.new \
> -K f239d9609e3f318b7afda7e4bb8db5b8734f504cf67f55e45dfe75f90d24fefc \
> -iv 8d6383b469f100d25293fb244ccb951e
$ cat secrets.txt.new
Encrypt file via AES-CBC

```

3.6.16 Using AES CBC mode decrypt a file

```

from __future__ import print_function, unicode_literals

import struct
import sys
import os

from binascii import unhexlify

from cryptography.hazmat.primitives import padding
from cryptography.hazmat.backends import default_backend
from cryptography.hazmat.primitives.ciphers import (
    Cipher,
    algorithms,
    modes)

backend = default_backend()

def decrypt(key, iv, ctext):
    alg = algorithms.AES(key)
    mode = modes.CBC(iv)
    cipher = Cipher(alg, mode, backend=backend)
    decryptor = cipher.decryptor()
    ptext = decryptor.update(ctext) + decryptor.finalize()

    unpadder = padding.PKCS7(128).unpadder() # 128 bit
    ptext = unpadder.update(ptext) + unpadder.finalize()

    return ptext

```

(continues on next page)

(continued from previous page)

```

if len(sys.argv) != 4:
    raise Exception("usage: cmd [key] [iv] [file]")

# read cipher text from file
with open(sys.argv[3], 'rb') as f:
    ciphertext = f.read()

# decrypt file
key, iv = unhexlify(sys.argv[1]), unhexlify(sys.argv[2])
plaintext = decrypt(key, iv, ciphertext)
print(plaintext)

```

output:

```

$ echo "Encrypt file via AES-CBC" > test.txt
$ key=`openssl rand -hex 32`
$ iv=`openssl rand -hex 16`
$ openssl enc -aes-256-cbc -in test.txt -out test.enc -K $key -iv $iv
$ python3 aes.py $key $iv test.enc

```

3.6.17 AES CBC mode encrypt via password (using cryptography)

```

from __future__ import print_function, unicode_literals

import base64
import struct
import sys
import os

from hashlib import md5, sha1

from cryptography.hazmat.primitives import padding
from cryptography.hazmat.backends import default_backend
from cryptography.hazmat.primitives.ciphers import (
    Cipher,
    algorithms,
    modes)

backend = default_backend()

def EVP_ByteToKey(pwd, md, salt, key_len, iv_len):
    buf = md(pwd + salt).digest()
    d = buf
    while len(buf) < (iv_len + key_len):
        d = md(d + pwd + salt).digest()
        buf += d
    return buf[:key_len], buf[key_len:key_len + iv_len]

```

(continues on next page)

(continued from previous page)

```
def aes_encrypt(pwd, ptext, md):
    key_len, iv_len = 32, 16

    # generate salt
    salt = os.urandom(8)

    # generate key, iv from password
    key, iv = EVP_BytesToKey(pwd, md, salt, key_len, iv_len)

    # pad plaintext
    pad = padding.PKCS7(128).padder()
    ptext = pad.update(ptext) + pad.finalize()

    # create an encryptor
    alg = algorithms.AES(key)
    mode = modes.CBC(iv)
    cipher = Cipher(alg, mode, backend=backend)
    encryptor = cipher.encryptor()

    # encrypt plain text
    ctext = encryptor.update(ptext) + encryptor.finalize()
    ctext = b'Salted__' + salt + ctext

    # encode base64
    ctext = base64.b64encode(ctext)
    return ctext

if len(sys.argv) != 2: raise Exception("usage: CMD [md]")

md = globals()[sys.argv[1]]

plaintext = sys.stdin.read().encode('utf-8')
pwd = b"password"

print(aes_encrypt(pwd, plaintext, md).decode('utf-8'))
```

output:

```
# with md5 digest
$ echo "Encrypt plaintext via AES-CBC from a given password" |\
> python3 aes.py md5 |\
> openssl base64 -d -A |\
> openssl aes-256-cbc -md md5 -d -k password
Encrypt plaintext via AES-CBC from a given password

# with sha1 digest
$ echo "Encrypt plaintext via AES-CBC from a given password" |\
> python3 aes.py sha1 |\
> openssl base64 -d -A |\
> openssl aes-256-cbc -md sha1 -d -k password
Encrypt plaintext via AES-CBC from a given password
```


3.6.18 AES CBC mode decrypt via password (using cryptography)

```

from __future__ import print_function, unicode_literals

import base64
import struct
import sys
import os

from hashlib import md5, sha1

from cryptography.hazmat.primitives import padding
from cryptography.hazmat.backends import default_backend
from cryptography.hazmat.primitives.ciphers import (
    Cipher,
    algorithms,
    modes)

backend = default_backend()

def EVP_ByteToKey(pwd, md, salt, key_len, iv_len):
    buf = md(pwd + salt).digest()
    d = buf
    while len(buf) < (iv_len + key_len):
        d = md(d + pwd + salt).digest()
        buf += d
    return buf[:key_len], buf[key_len:key_len + iv_len]

def aes_decrypt(pwd, ctext, md):
    ctext = base64.b64decode(ctext)

    # check magic
    if ctext[:8] != b'Salted__':
        raise Exception("bad magic number")

    # get salt
    salt = ctext[8:16]

    # generate key, iv from password
    key, iv = EVP_ByteToKey(pwd, md, salt, 32, 16)

    # decrypt
    alg = algorithms.AES(key)
    mode = modes.CBC(iv)
    cipher = Cipher(alg, mode, backend=backend)
    decryptor = cipher.decryptor()
    ptext = decryptor.update(ctext[16:]) + decryptor.finalize()

    # unpad plaintext
    unpadder = padding.PKCS7(128).unpadder() # 128 bit
    ptext = unpadder.update(ptext) + unpadder.finalize()
    return ptext.strip()

```

(continues on next page)

(continued from previous page)

```

if len(sys.argv) != 2: raise Exception("usage: CMD [md]")

md = globals()[sys.argv[1]]

ciphertext = sys.stdin.read().encode('utf-8')
pwd = b"password"

print(aes_decrypt(pwd, ciphertext, md).decode('utf-8'))

```

output:

```

# with md5 digest
$ echo "Decrypt ciphertext via AES-CBC from a given password" | \
> openssl aes-256-cbc -e -md md5 -salt -A -k password | \
> openssl base64 -e -A | \
> python3 aes.py md5
Decrypt ciphertext via AES-CBC from a given password

# with sha1 digest
$ echo "Decrypt ciphertext via AES-CBC from a given password" | \
> openssl aes-256-cbc -e -md sha1 -salt -A -k password | \
> openssl base64 -e -A | \
> python3 aes.py sha1
Decrypt ciphertext via AES-CBC from a given password

```

3.6.19 AES CBC mode encrypt via password (using pycrypto)

```

from __future__ import print_function, unicode_literals

import struct
import base64
import sys

from hashlib import md5, sha1
from Crypto.Cipher import AES
from Crypto.Random.random import getrandbits

# AES CBC requires blocks to be aligned on 16-byte boundaries.
BS = 16

pad = lambda s: s + (BS - len(s) % BS) * chr(BS - len(s) % BS).encode('utf-8')
unpad = lambda s: s[0:-ord(s[-1])]

def EVP_ByteToKey(pwd, md, salt, key_len, iv_len):
    buf = md(pwd + salt).digest()
    d = buf
    while len(buf) < (iv_len + key_len):
        d = md(d + pwd + salt).digest()
        buf += d

```

(continues on next page)

(continued from previous page)

```

    return buf[:key_len], buf[key_len:key_len + iv_len]

def aes_encrypt(pwd, plaintext, md):
    key_len, iv_len = 32, 16

    # generate salt
    salt = struct.pack('=Q', getrandbits(64))

    # generate key, iv from password
    key, iv = EVP_ByteToKey(pwd, md, salt, key_len, iv_len)

    # pad plaintext
    plaintext = pad(plaintext)

    # create a cipher object
    cipher = AES.new(key, AES.MODE_CBC, iv)

    # ref: openssl/apps/enc.c
    ciphertext = b'Salted__' + salt + cipher.encrypt(plaintext)

    # encode base64
    ciphertext = base64.b64encode(ciphertext)
    return ciphertext

if len(sys.argv) != 2: raise Exception("usage: CMD [md]")

md = globals()[sys.argv[1]]

plaintext = sys.stdin.read().encode('utf-8')
pwd = b"password"

print(aes_encrypt(pwd, plaintext, md).decode('utf-8'))

```

output:

```

# with md5 digest
$ echo "Encrypt plaintext via AES-CBC from a given password" |\
> python3 aes.py md5 |\
> openssl base64 -d -A |\
> openssl aes-256-cbc -md md5 -d -k password
Encrypt plaintext via AES-CBC from a given password

# with sha1 digest
$ echo "Encrypt plaintext via AES-CBC from a given password" |\
> python3 aes.py sha1 |\
> openssl base64 -d -A |\
> openssl aes-256-cbc -md sha1 -d -k password
Encrypt plaintext via AES-CBC from a given password

```

3.6.20 AES CBC mode decrypt via password (using pycrypto)

```
from __future__ import print_function, unicode_literals

import struct
import base64
import sys

from hashlib import md5, sha1
from Crypto.Cipher import AES
from Crypto.Random.random import getrandbits

# AES CBC requires blocks to be aligned on 16-byte boundaries.
BS = 16

unpad = lambda s : s[0:-s[-1]]

def EVP_ByteToKey(pwd, md, salt, key_len, iv_len):
    buf = md(pwd + salt).digest()
    d = buf
    while len(buf) < (iv_len + key_len):
        d = md(d + pwd + salt).digest()
        buf += d
    return buf[:key_len], buf[key_len:key_len + iv_len]

def aes_decrypt(pwd, ciphertext, md):
    ciphertext = base64.b64decode(ciphertext)

    # check magic
    if ciphertext[:8] != b'Salted__':
        raise Exception("bad magic number")

    # get salt
    salt = ciphertext[8:16]

    # get key, iv
    key, iv = EVP_ByteToKey(pwd, md, salt, 32, 16)

    # decrypt
    cipher = AES.new(key, AES.MODE_CBC, iv)
    return unpad(cipher.decrypt(ciphertext[16:])).strip()

if len(sys.argv) != 2: raise Exception("usage: CMD [md]")

md = globals()[sys.argv[1]]

ciphertext = sys.stdin.read().encode('utf-8')
pwd = b"password"

print(aes_decrypt(pwd, ciphertext, md).decode('utf-8'))
```

output:

```
# with md5 digest
$ echo "Decrypt ciphertext via AES-CBC from a given password" | \
> openssl aes-256-cbc -e -md md5 -salt -A -k password | \
> openssl base64 -e -A | \
> python3 aes.py md5
Decrypt ciphertext via AES-CBC from a given password

# with sha1 digest
$ echo "Decrypt ciphertext via AES-CBC from a given password" | \
> openssl aes-256-cbc -e -md sha1 -salt -A -k password | \
> openssl base64 -e -A | \
> python3 aes.py sha1
Decrypt ciphertext via AES-CBC from a given password
```

3.6.21 Ephemeral Diffie Hellman Key Exchange via cryptography

```
>>> from cryptography.hazmat.backends import default_backend
>>> from cryptography.hazmat.primitives.asymmetric import dh
>>> params = dh.generate_parameters(2, 512, default_backend())
>>> a_key = params.generate_private_key() # alice's private key
>>> b_key = params.generate_private_key() # bob's private key
>>> a_pub_key = a_key.public_key()
>>> b_pub_key = b_key.public_key()
>>> a_shared_key = a_key.exchange(b_pub_key)
>>> b_shared_key = b_key.exchange(a_pub_key)
>>> a_shared_key == b_shared_key
True
```

3.6.22 Calculate DH shared key manually via cryptography

```
>>> from cryptography.hazmat.backends import default_backend
>>> from cryptography.hazmat.primitives.asymmetric import dh
>>> from cryptography.utils import int_from_bytes
>>> a_key = params.generate_private_key() # alice's private key
>>> b_key = params.generate_private_key() # bob's private key
>>> a_pub_key = a_key.public_key()
>>> b_pub_key = b_key.public_key()
>>> shared_key = int_from_bytes(a_key.exchange(b_pub_key), 'big')
>>> shared_key_manual = pow(a_pub_key.public_numbers().y,
...                          b_key.private_numbers().x,
...                          params.parameter_numbers().p)
>>> shared_key == shared_key_manual
True
```

3.6.23 Calculate DH shared key from (p, g, pubkey)

```
from cryptography.hazmat.backends import default_backend
from cryptography.hazmat.primitives.asymmetric import dh
from cryptography.utils import int_from_bytes

backend = default_backend()

p = int("11859949538425015739337467917303613431031019140213666"
        "12902540730065402658508634532306628480096346320424639"
        "0256567934582260424238844463330887962689642467123")

g = 2

y = int("32155788395534640648739966373159697798396966919821525"
        "72238852825117261342483718574508213761865276905503199"
        "969908098203345481366464874759377454476688391248")

x = int("409364065449673443397833358558926598469347813468816037"
        "2684518471169824907334504631949214050699990008617231539"
        "7147035896687401350877308899732826446337707128")

params = dh.DHParameterNumbers(p, g)
public = dh.DHPublicNumbers(y, params)
private = dh.DHPrivateNumbers(x, public)

key = private.private_key(backend)
shared_key = key.exchange(public.public_key(backend))

# check shared key
shared_key = int_from_bytes(shared_key, 'big')
shared_key_manual = pow(y, x, p) #  $y^x \bmod p$ 

assert shared_key == shared_key_manual
```

3.7 Secure Shell

Table of Contents

- *Secure Shell*
 - *Login ssh*

3.7.1 Login ssh

```
# ssh me@localhost "uname"
```

```
from paramiko.client import SSHClient
with SSHClient() as ssh:
    ssh.connect("localhost", username="me", password="pwd")
    stdin, stdout, stderr = ssh.exec_command("uname")
    print(stdout.read())
```

```
# ssh -p 2222 me@localhost "uname"
```

```
from paramiko.client import SSHClient
with SSHClient() as ssh:
    ssh.connect("localhost", 2222, username="me", password="pwd")
    stdin, stdout, stderr = ssh.exec_command("uname")
    print(stdout.read())
```

```
# ignore known hosts
# ssh -o StrictHostKeyChecking=no \
#     -o UserKnownHostsFile=/dev/null \
#     me@localhost "uname"
```

```
import paramiko
from paramiko.client import SSHClient
with SSHClient() as ssh:
    ssh.set_missing_host_key_policy(paramiko.AutoAddPolicy())
    ssh.connect("localhost", username="me", password="pwd")
    stdin, stdout, stderr = ssh.exec_command("uname")
    print(stdout.read())
```

```
# ssh-keygen -f key -m pem -t rsa
# ssh-copy-id -i key me@localhost
# ssh -i key me@localhost "uname"
```

```
with SSHClient() as ssh:
    ssh.connect('localhost', username="me", key_filename="key")
    stdin, stdout, stderr = ssh.exec_command("uname")
    print(stdout.read())
```

```
# ssh-keygen -m pem -f key -t rsa -P passphrase
# eval $(ssh-agent)
# ssh-add key
# ssh -i key me@localhost
```

3.8 Boto3

3.9 Test

Table of Contents

- *Test*
 - *A simple Python unittest*
 - *Python unittest setup & teardown hierarchy*
 - *Different module of setUp & tearDown hierarchy*
 - *Run tests via unittest.TextTestRunner*
 - *Test raise exception*
 - *Pass arguments into a TestCase*
 - *Group multiple testcases into a suite*
 - *Group multiple tests from different TestCase*
 - *Skip some tests in the TestCase*
 - *Monolithic Test*
 - *Cross-module variables to Test files*
 - *skip setup & teardown when the test is skipped*
 - *Re-using old test code*
 - *Testing your document is right*
 - *Re-using doctest to unittest*
 - *Customize test report*
 - *Mock - using @patch substitute original method*
 - *What with unittest.mock.patch do?*
 - *Mock - substitute open*

3.9.1 A simple Python unittest

```
# python unittests only run the function with prefix "test"

>>> from __future__ import print_function
>>> import unittest
>>> class TestFoo(unittest.TestCase):
...     def test_foo(self):
...         self.assertTrue(True)
...     def fun_not_run(self):
...         print("no run")
... 
```

(continues on next page)

(continued from previous page)

```

>>> unittest.main()
.
-----
Ran 1 test in 0.000s

OK
>>> import unittest
>>> class TestFail(unittest.TestCase):
...     def test_false(self):
...         self.assertTrue(False)
...
>>> unittest.main()
F
=====
FAIL: test_false (__main__.TestFail)
-----
Traceback (most recent call last):
  File "<stdin>", line 3, in test_false
AssertionError: False is not true
-----
Ran 1 test in 0.000s

FAILED (failures=1)

```

3.9.2 Python unittest setup & teardown hierarchy

```

from __future__ import print_function

import unittest

def fib(n):
    return 1 if n<=2 else fib(n-1)+fib(n-2)

def setUpModule():
    print("setup module")
def tearDownModule():
    print("teardown module")

class TestFib(unittest.TestCase):

    def setUp(self):
        print("setUp")
        self.n = 10
    def tearDown(self):
        print("tearDown")
        del self.n
    @classmethod
    def setUpClass(cls):
        print("setUpClass")

```

(continues on next page)

(continued from previous page)

```

    @classmethod
    def tearDownClass(cls):
        print("tearDownClass")
    def test_fib_assert_equal(self):
        self.assertEqual(fib(self.n), 55)
    def test_fib_assert_true(self):
        self.assertTrue(fib(self.n) == 55)

if __name__ == "__main__":
    unittest.main()

```

output:

```

$ python test.py
setup module
setUpClass
setUp
tearDown
.setUp
tearDown
.tearDownClass
teardown module

```

```

-----
Ran 2 tests in 0.000s

```

```

OK

```

3.9.3 Different module of setUp & tearDown hierarchy

```

# test_module.py
from __future__ import print_function

import unittest

class TestFoo(unittest.TestCase):
    @classmethod
    def setUpClass(self):
        print("foo setUpClass")
    @classmethod
    def tearDownClass(self):
        print("foo tearDownClass")
    def setUp(self):
        print("foo setUp")
    def tearDown(self):
        print("foo tearDown")
    def test_foo(self):
        self.assertTrue(True)

class TestBar(unittest.TestCase):

```

(continues on next page)

(continued from previous page)

```

def setUp(self):
    print("bar setUp")
def tearDown(self):
    print("bar tearDown")
def test_bar(self):
    self.assertTrue(True)

# test.py
from __future__ import print_function

from test_module import TestFoo
from test_module import TestBar
import test_module
import unittest

def setUpModule():
    print("setUpModule")

def tearDownModule():
    print("tearDownModule")

if __name__ == "__main__":
    test_module.setUpModule = setUpModule
    test_module.tearDownModule = tearDownModule
    suite1 = unittest.TestLoader().loadTestsFromTestCase(TestFoo)
    suite2 = unittest.TestLoader().loadTestsFromTestCase(TestBar)
    suite = unittest.TestSuite([suite1,suite2])
    unittest.TextTestRunner().run(suite)

```

output:

```

$ python test.py
setUpModule
foo setUpClass
foo setUp
foo tearDown
.foo tearDownClass
bar setUp
bar tearDown
.tearDownModule

-----
Ran 2 tests in 0.000s

OK

```

3.9.4 Run tests via unittest.TextTestRunner

```
>>> import unittest
>>> class TestFoo(unittest.TestCase):
...     def test_foo(self):
...         self.assertTrue(True)
...     def test_bar(self):
...         self.assertFalse(False)

>>> suite = unittest.TestLoader().loadTestsFromTestCase(TestFoo)
>>> unittest.TextTestRunner(verbosity=2).run(suite)
test_bar (__main__.TestFoo) ... ok
test_foo (__main__.TestFoo) ... ok
```

Ran 2 tests in 0.000s

OK

3.9.5 Test raise exception

```
>>> import unittest

>>> class TestRaiseException(unittest.TestCase):
...     def test_raise_except(self):
...         with self.assertRaises(SystemError):
...             raise SystemError
>>> suite_loader = unittest.TestLoader()
>>> suite = suite_loader.loadTestsFromTestCase(TestRaiseException)
>>> unittest.TextTestRunner().run(suite)
.
```

Ran 1 test in 0.000s

OK

```
>>> class TestRaiseFail(unittest.TestCase):
...     def test_raise_fail(self):
...         with self.assertRaises(SystemError):
...             pass
>>> suite = unittest.TestLoader().loadTestsFromTestCase(TestRaiseFail)
>>> unittest.TextTestRunner(verbosity=2).run(suite)
test_raise_fail (__main__.TestRaiseFail) ... FAIL
```

=====
FAIL: test_raise_fail (__main__.TestRaiseFail)

Traceback (most recent call last):
 File "<stdin>", line 4, in test_raise_fail
AssertionError: SystemError not raised

(continues on next page)

(continued from previous page)

```
Ran 1 test in 0.000s
```

```
FAILED (failures=1)
```

3.9.6 Pass arguments into a TestCase

```
>>> from __future__ import print_function
>>> import unittest
>>> class TestArg(unittest.TestCase):
...     def __init__(self, testname, arg):
...         super(TestArg, self).__init__(testname)
...         self._arg = arg
...     def setUp(self):
...         print("setUp:", self._arg)
...     def test_arg(self):
...         print("test_arg:", self._arg)
...         self.assertTrue(True)
...
>>> suite = unittest.TestSuite()
>>> suite.addTest(TestArg('test_arg', 'foo'))
>>> unittest.TextTestRunner(verbosity=2).run(suite)
test_arg (__main__.TestArg) ... setUp: foo
test_arg: foo
ok
```

```
-----
Ran 1 test in 0.000s
```

```
OK
```

3.9.7 Group multiple testcases into a suite

```
>>> import unittest
>>> class TestFooBar(unittest.TestCase):
...     def test_foo(self):
...         self.assertTrue(True)
...     def test_bar(self):
...         self.assertTrue(True)
...
>>> class TestHelloWorld(unittest.TestCase):
...     def test_hello(self):
...         self.assertEqual("Hello", "Hello")
...     def test_world(self):
...         self.assertEqual("World", "World")
...
>>> suite_loader = unittest.TestLoader()
>>> suite1 = suite_loader.loadTestsFromTestCase(TestFooBar)
>>> suite2 = suite_loader.loadTestsFromTestCase(TestHelloWorld)
>>> suite = unittest.TestSuite([suite1, suite2])
```

(continues on next page)

(continued from previous page)

```
>>> unittest.TextTestRunner(verbosity=2).run(suite)
test_bar (__main__.TestFooBar) ... ok
test_foo (__main__.TestFooBar) ... ok
test_hello (__main__.TestHelloWorld) ... ok
test_world (__main__.TestHelloWorld) ... ok
```

```
-----
Ran 4 tests in 0.000s
```

```
OK
```

3.9.8 Group multiple tests from different TestCase

```
>>> import unittest
>>> class TestFoo(unittest.TestCase):
...     def test_foo(self):
...         assert "foo" == "foo"
...
>>> class TestBar(unittest.TestCase):
...     def test_bar(self):
...         assert "bar" == "bar"
...
>>> suite = unittest.TestSuite()
>>> suite.addTest(TestFoo('test_foo'))
>>> suite.addTest(TestBar('test_bar'))
>>> unittest.TextTestRunner(verbosity=2).run(suite)
test_foo (__main__.TestFoo) ... ok
test_bar (__main__.TestBar) ... ok
```

```
-----
Ran 2 tests in 0.001s
```

```
OK
```

3.9.9 Skip some tests in the TestCase

```
>>> import unittest
>>> RUN_FOO = False
>>> DONT_RUN_BAR = False
>>> class TestSkip(unittest.TestCase):
...     def test_always_run(self):
...         self.assertTrue(True)
...     @unittest.skip("always skip this test")
...     def test_always_skip(self):
...         raise RuntimeError
...     @unittest.skipIf(RUN_FOO == False, "demo skipIf")
...     def test_skipif(self):
...         raise RuntimeError
...     @unittest.skipUnless(DONT_RUN_BAR == True, "demo skipUnless")
```

(continues on next page)

(continued from previous page)

```

...     def test_skipunless(self):
...         raise RuntimeError
...
>>> suite = unittest.TestLoader().loadTestsFromTestCase(TestSkip)
>>> unittest.TextTestRunner(verbosity=2).run(suite)
test_always_run (__main__.TestSkip) ... ok
test_always_skip (__main__.TestSkip) ... skipped 'always skip this test'
test_skipif (__main__.TestSkip) ... skipped 'demo skipIf'
test_skipunless (__main__.TestSkip) ... skipped 'demo skipUnless'

-----
Ran 4 tests in 0.000s

OK (skipped=3)

```

3.9.10 Monolithic Test

```

>>> from __future__ import print_function
>>> import unittest
>>> class Monolithic(unittest.TestCase):
...     def step1(self):
...         print('step1')
...     def step2(self):
...         print('step2')
...     def step3(self):
...         print('step3')
...     def _steps(self):
...         for attr in sorted(dir(self)):
...             if not attr.startswith('step'):
...                 continue
...             yield attr
...     def test_foo(self):
...         for _s in self._steps():
...             try:
...                 getattr(self, _s)()
...             except Exception as e:
...                 self.fail('{} failed({})'.format(attr, e))
...
>>> suite = unittest.TestLoader().loadTestsFromTestCase(Monolithic)
>>> unittest.TextTestRunner().run(suite)
step1
step2
step3
.
-----
Ran 1 test in 0.000s

OK
<unittest.runner.TextTestResult run=1 errors=0 failures=0>

```

3.9.11 Cross-module variables to Test files

test_foo.py

```
from __future__ import print_function

import unittest

print(conf)

class TestFoo(unittest.TestCase):
    def test_foo(self):
        print(conf)

    @unittest.skipIf(conf.isskip==True, "skip test")
    def test_skip(self):
        raise RuntimeError
```

test_bar.py

```
from __future__ import print_function

import unittest
import __builtin__

if __name__ == "__main__":
    conf = type('TestConf', (object,), {})
    conf.isskip = True

    # make a cross-module variable
    __builtin__.conf = conf
    module = __import__('test_foo')
    loader = unittest.TestLoader()
    suite = loader.loadTestsFromTestCase(module.TestFoo)
    unittest.TextTestRunner(verbosity=2).run(suite)
```

output:

```
$ python test_bar.py
<class '__main__.TestConf'>
test_foo (test_foo.TestFoo) ... <class '__main__.TestConf'>
ok
test_skip (test_foo.TestFoo) ... skipped 'skip test'

-----
Ran 2 tests in 0.000s

OK (skipped=1)
```


3.9.12 skip setup & teardown when the test is skipped

```
>>> from __future__ import print_function
>>> import unittest
>>> class TestSkip(unittest.TestCase):
...     def setUp(self):
...         print("setUp")
...     def tearDown(self):
...         print("tearDown")
...     @unittest.skip("skip this test")
...     def test_skip(self):
...         raise RuntimeError
...     def test_not_skip(self):
...         self.assertTrue(True)
...
>>> suite = unittest.TestLoader().loadTestsFromTestCase(TestSkip)
>>> unittest.TextTestRunner(verbosity=2).run(suite)
test_not_skip (__main__.TestSkip) ... setUp
tearDown
ok
test_skip (__main__.TestSkip) ... skipped 'skip this test'

-----
Ran 2 tests in 0.000s

OK (skipped=1)
```

3.9.13 Re-using old test code

```
>>> from __future__ import print_function
>>> import unittest
>>> def old_func_test():
...     assert "Hello" == "Hello"
...
>>> def old_func_setup():
...     print("setup")
...
>>> def old_func_teardown():
...     print("teardown")
...
>>> testcase = unittest.FunctionTestCase(old_func_test,
...                                     setUp=old_func_setup,
...                                     tearDown=old_func_teardown)
>>> suite = unittest.TestSuite([testcase])
>>> unittest.TextTestRunner().run(suite)
setup
teardown
.
-----
Ran 1 test in 0.000s
```

(continues on next page)

(continued from previous page)

```
OK
<unittest.runner.TextTestResult run=1 errors=0 failures=0>
```

3.9.14 Testing your document is right

```
"""
This is an example of doctest

>>> fib(10)
55
"""

def fib(n):
    """ This function calculate fib number.

    Example:

        >>> fib(10)
        55
        >>> fib(-1)
        Traceback (most recent call last):
        ...
        ValueError
    """
    if n < 0:
        raise ValueError('')
    return 1 if n<=2 else fib(n-1) + fib(n-2)

if __name__ == "__main__":
    import doctest
    doctest.testmod()
```

output:

```
$ python demo_doctest.py -v
Trying:
fib(10)
Expecting:
55
ok
Trying:
fib(10)
Expecting:
55
ok
Trying:
fib(-1)
Expecting:
Traceback (most recent call last):
...
```

(continues on next page)

(continued from previous page)

```

ValueError
ok
2 items passed all tests:
1 tests in __main__
2 tests in __main__.fib
3 tests in 2 items.
3 passed and 0 failed.
Test passed.

```

3.9.15 Re-using doctest to unittest

```

import unittest
import doctest

"""
This is an example of doctest

>>> fib(10)
55
"""

def fib(n):
    """ This function calculate fib number.

    Example:

        >>> fib(10)
        55
        >>> fib(-1)
        Traceback (most recent call last):
            ...
        ValueError
    """
    if n < 0:
        raise ValueError('')
    return 1 if n<=2 else fib(n-1) + fib(n-2)

if __name__ == "__main__":
    finder = doctest.DocTestFinder()
    suite = doctest.DocTestSuite(test_finder=finder)
    unittest.TextTestRunner(verbosity=2).run(suite)

```

output:

```

fib (__main__)
Doctest: __main__.fib ... ok

-----

Ran 1 test in 0.023s

OK

```

3.9.16 Customize test report

```

from unittest import (
    TestCase,
    TestLoader,
    TextTestResult,
    TextTestRunner)

from pprint import pprint
import unittest
import os

OK = 'ok'
FAIL = 'fail'
ERROR = 'error'
SKIP = 'skip'

class JsonTestResult(TextTestResult):

    def __init__(self, stream, descriptions, verbosity):
        super_class = super(JsonTestResult, self)
        super_class.__init__(stream, descriptions, verbosity)

        # TextTestResult has no successes attr
        self.successes = []

    def addSuccess(self, test):
        # addSuccess do nothing, so we need to overwrite it.
        super(JsonTestResult, self).addSuccess(test)
        self.successes.append(test)

    def json_append(self, test, result, out):
        suite = test.__class__.__name__
        if suite not in out:
            out[suite] = {OK: [], FAIL: [], ERROR: [], SKIP: []}
        if result is OK:
            out[suite][OK].append(test._testMethodName)
        elif result is FAIL:
            out[suite][FAIL].append(test._testMethodName)
        elif result is ERROR:
            out[suite][ERROR].append(test._testMethodName)
        elif result is SKIP:
            out[suite][SKIP].append(test._testMethodName)
        else:
            raise KeyError("No such result: {}".format(result))
        return out

    def jsonify(self):
        json_out = dict()
        for t in self.successes:
            json_out = self.json_append(t, OK, json_out)

        for t, _ in self.failures:

```

(continues on next page)

(continued from previous page)

```

        json_out = self.json_append(t, FAIL, json_out)

    for t, _ in self.errors:
        json_out = self.json_append(t, ERROR, json_out)

    for t, _ in self.skipped:
        json_out = self.json_append(t, SKIP, json_out)

    return json_out

class TestSimple(TestCase):

    def test_ok_1(self):
        foo = True
        self.assertTrue(foo)

    def test_ok_2(self):
        bar = True
        self.assertTrue(bar)

    def test_fail(self):
        baz = False
        self.assertTrue(baz)

    def test_raise(self):
        raise RuntimeError

    @unittest.skip("Test skip")
    def test_skip(self):
        raise NotImplementedError

if __name__ == '__main__':
    # redirector default output of unittest to /dev/null
    with open(os.devnull, 'w') as null_stream:
        # new a runner and overwrite resultclass of runner
        runner = TextTestRunner(stream=null_stream)
        runner.resultclass = JsonTestResult

        # create a testsuite
        suite = TestLoader().loadTestsFromTestCase(TestSimple)

        # run the testsuite
        result = runner.run(suite)

        # print json output
        pprint(result.jsonify())

```

output:

```

$ python test.py
{'TestSimple': {'error': ['test_raise'],
                  'fail': ['test_fail'],

```

(continues on next page)

(continued from previous page)

```
'ok': ['test_ok_1', 'test_ok_2'],
'skip': ['test_skip']}]}
```

3.9.17 Mock - using @patch substitute original method

```
# python-3.3 or above

>>> from unittest.mock import patch
>>> import os
>>> def fake_remove(path, *a, **k):
...     print("remove done")
...
>>> @patch('os.remove', fake_remove)
... def test():
...     try:
...         os.remove('%$!?!&*') # fake os.remove
...     except OSError as e:
...         print(e)
...     else:
...         print('test success')
...
>>> test()
remove done
test success
```

Note: Without mock, above test will always fail.

```
>>> import os
>>> def test():
...     try:
...         os.remove('%$!?!&*')
...     except OSError as e:
...         print(e)
...     else:
...         print('test success')
...
>>> test()
[Errno 2] No such file or directory: '%$!?!&*'
```

3.9.18 What with `unittest.mock.patch` do?

```

from unittest.mock import patch
import os

PATH = '$@!%?&'

def fake_remove(path):
    print("Fake remove")

class SimplePatch:

    def __init__(self, target, new):
        self._target = target
        self._new = new

    def get_target(self, target):
        target, attr = target.rsplit('.', 1)
        getter = __import__(target)
        return getter, attr

    def __enter__(self):
        orig, attr = self.get_target(self._target)
        self.orig, self.attr = orig, attr
        self.orig_attr = getattr(orig, attr)
        setattr(orig, attr, self._new)
        return self._new

    def __exit__(self, *exc_info):
        setattr(self.orig, self.attr, self.orig_attr)
        del self.orig_attr

print('---> inside unittest.mock.patch scope')
with patch('os.remove', fake_remove):
    os.remove(PATH)

print('---> inside simple patch scope')
with SimplePatch('os.remove', fake_remove):
    os.remove(PATH)

print('---> outside patch scope')
try:
    os.remove(PATH)
except OSError as e:
    print(e)

```

output:

```

$ python3 simple_patch.py
---> inside unittest.mock.patch scope
Fake remove

```

(continues on next page)

(continued from previous page)

```
---> inside simple patch scope
Fake remove
---> outside patch scope
[Errno 2] No such file or directory: '$@!%?&'
```

3.9.19 Mock - substitute open

```
>>> import urllib
>>> from unittest.mock import patch, mock_open
>>> def send_req(url):
...     with urllib.request.urlopen(url) as f:
...         if f.status == 200:
...             return f.read()
...         raise urllib.error.URLError
...
>>> fake_html = b'<html><h1>Mock Content</h1></html>'
>>> mock_urlopen = mock_open(read_data=fake_html)
>>> ret = mock_urlopen.return_value
>>> ret.status = 200
>>> @patch('urllib.request.urlopen', mock_urlopen)
... def test_send_req_success():
...     try:
...         ret = send_req('http://www.mockurl.com')
...         assert ret == fake_html
...     except Exception as e:
...         print(e)
...     else:
...         print('test send_req success')
...
>>> test_send_req_success()
test send_req success
>>> ret = mock_urlopen.return_value
>>> ret.status = 404
>>> @patch('urllib.request.urlopen', mock_urlopen)
... def test_send_req_fail():
...     try:
...         ret = send_req('http://www.mockurl.com')
...         assert ret == fake_html
...     except Exception as e:
...         print('test fail success')
...
>>> test_send_req_fail()
test fail success
```


3.10 C Extensions

Occasionally, it is unavoidable for pythoneers to write a C extension. For example, porting C libraries or new system calls to Python requires to implement new object types through C extension. In order to provide a brief glance on how C extension works. This cheat sheet mainly focuses on writing a Python C extension.

Note that the C extension interface is specific to official CPython. It is likely that extension modules do not work on other Python implementations such as [PyPy](#). Even if official CPython, the Python C API may be not compatible with different versions, e.g., Python2 and Python3. Therefore, if extension modules are considered to be run on other Python interpreters, it would be better to use [ctypes](#) module or [cffi](#).

Table of Contents

- *C Extensions*
 - *Simple setup.py*
 - *Customize CFLAGS*
 - *Doc String*
 - *Simple C Extension*
 - *Release the GIL*
 - *Acquire the GIL*
 - *Get Reference Count*
 - *Parse Arguments*
 - *Calling Python Functions*
 - *Raise Exception*
 - *Customize Exception*
 - *Iterate a List*
 - *Iterate a Dictionary*
 - *Simple Class*
 - *Simple Class with Members and Methods*
 - *Simple Class with Getter and Setter*
 - *Inherit from Other Class*
 - *Run a Python Command*
 - *Run a Python File*
 - *Import a Python Module*
 - *Import everything of a Module*
 - *Access Attributes*
 - *Performance of C Extension*
 - *Performance of ctypes*
 - *ctypes Error handling*

3.10.1 Simple setup.py

```
from distutils.core import setup, Extension

ext = Extension('foo', sources=['foo.c'])
setup(name="Foo", version="1.0", ext_modules=[ext])
```

3.10.2 Customize CFLAGS

```
import sysconfig
from distutils.core import setup, Extension

cflags = sysconfig.get_config_var("CFLAGS")

extra_compile_args = cflags.split()
extra_compile_args += ["-Wextra"]

ext = Extension(
    "foo", ["foo.c"],
    extra_compile_args=extra_compile_args
)

setup(name="foo", version="1.0", ext_modules=[ext])
```

3.10.3 Doc String

```
PyDoc_STRVAR(doc_mod, "Module document\n");
PyDoc_STRVAR(doc_foo, "foo() -> None\n\nFoo doc");

static PyMethodDef methods[] = {
    {"foo", (PyCFunction)foo, METH_NOARGS, doc_foo},
    {NULL, NULL, 0, NULL}
};

static struct PyModuleDef module = {
    .m_base = PyModuleDef_HEAD_INIT,
    .m_name = "Foo",
    .m_doc = doc_mod,
    .m_size = -1,
    .m_methods = methods
};
```

3.10.4 Simple C Extension

foo.c

```
#include <Python.h>

PyDoc_STRVAR(doc_mod, "Module document\n");
PyDoc_STRVAR(doc_foo, "foo() -> None\n\nFoo doc");

static PyObject* foo(PyObject* self)
{
    PyObject* s = PyUnicode_FromString("foo");
    PyObject_Print(s, stdout, 0);
    Py_RETURN_NONE;
}

static PyMethodDef methods[] = {
    {"foo", (PyCFunction)foo, METH_NOARGS, doc_foo},
    {NULL, NULL, 0, NULL}
};

static struct PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "Foo", doc_mod, -1, methods
};

PyMODINIT_FUNC PyInit_foo(void)
{
    return PyModule_Create(&module);
}
```

output:

```
$ python setup.py -q build
$ python setup.py -q install
$ python -c "import foo; foo.foo()"
'foo'
```

3.10.5 Release the GIL

```
#include <Python.h>

static PyObject* foo(PyObject* self)
{
    Py_BEGIN_ALLOW_THREADS
    sleep(3);
    Py_END_ALLOW_THREADS
    Py_RETURN_NONE;
}

static PyMethodDef methods[] = {
    {"foo", (PyCFunction)foo, METH_NOARGS, NULL},
    {NULL, NULL, 0, NULL}
}
```

(continues on next page)

(continued from previous page)

```
};

static struct PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "Foo", NULL, -1, methods
};

PyMODINIT_FUNC PyInit_foo(void)
{
    return PyModule_Create(&module);
}
```

output:

```
$ python setup.py -q build
$ python setup.py -q install
$ python -c "
> import threading
> import foo
> from datetime import datetime
> def f(n):
>     now = datetime.now()
>     print(f'{now}: thread {n}')
>     foo.foo()
> ts = [threading.Thread(target=f, args=(n,)) for n in range(3)]
> [t.start() for t in ts]
> [t.join() for t in ts]"
2018-11-04 20:15:34.860454: thread 0
2018-11-04 20:15:34.860592: thread 1
2018-11-04 20:15:34.860705: thread 2
```

In C extension, blocking I/O should be inserted into a block which is wrapped by `Py_BEGIN_ALLOW_THREADS` and `Py_END_ALLOW_THREADS` for releasing the GIL temporarily; Otherwise, a blocking I/O operation has to wait until previous operation finish. For example

```
#include <Python.h>

static PyObject* foo(PyObject* self)
{
    sleep(3);
    Py_RETURN_NONE;
}

static PyMethodDef methods[] = {
    {"foo", (PyCFunction)foo, METH_NOARGS, NULL},
    {NULL, NULL, 0, NULL}
};

static struct PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "Foo", NULL, -1, methods
};

PyMODINIT_FUNC PyInit_foo(void)
```

(continues on next page)

(continued from previous page)

```
{
    return PyModule_Create(&module);
}
```

output:

```
$ python -c "
> import threading
> import foo
> from datetime import datetime
> def f(n):
>     now = datetime.now()
>     print(f'{now}: thread {n}')
>     foo.foo()
> ts = [threading.Thread(target=f, args=(n,)) for n in range(3)]
> [t.start() for t in ts]
> [t.join() for t in ts]"
2018-11-04 20:16:44.055932: thread 0
2018-11-04 20:16:47.059718: thread 1
2018-11-04 20:16:50.063579: thread 2
```

Warning: The GIL can only be safely released when there is **NO** Python C API functions between Py_BEGIN_ALLOW_THREADS and Py_END_ALLOW_THREADS.

3.10.6 Acquire the GIL

```
#include <pthread.h>
#include <Python.h>

typedef struct {
    PyObject *sec;
    PyObject *py_callback;
} foo_args;

void *
foo_thread(void *args)
{
    long n = -1;
    PyObject *rv = NULL, *sec = NULL, *py_callback = NULL;
    foo_args *a = NULL;

    if (!args)
        return NULL;

    a = (foo_args *)args;
    sec = a->sec;
    py_callback = a->py_callback;

    n = PyLong_AsLong(sec);
```

(continues on next page)

(continued from previous page)

```

    if ((n == -1) && PyErr_Occurred()) {
        return NULL;
    }

    sleep(n); // slow task

    // acquire the GIL
    PyGILState_STATE state = PyGILState_Ensure();
    rv = PyObject_CallFunction(py_callback, "s", "Awesome Python!");
    // release the GIL
    PyGILState_Release(state);
    Py_XDECREF(rv);
    return NULL;
}

static PyObject *
foo(PyObject *self, PyObject *args)
{
    long i = 0, n = 0;
    pthread_t *arr = NULL;
    PyObject *py_callback = NULL;
    PyObject *sec = NULL, *num = NULL;
    PyObject *rv = NULL;
    foo_args a = {};

    if (!PyArg_ParseTuple(args, "000:callback", &num, &sec, &py_callback))
        return NULL;

    // allow releasing GIL
    Py_BEGIN_ALLOW_THREADS

    if (!PyLong_Check(sec) || !PyLong_Check(num)) {
        PyErr_SetString(PyExc_TypeError, "should be int");
        goto error;
    }

    if (!PyCallable_Check(py_callback)) {
        PyErr_SetString(PyExc_TypeError, "should be callable");
        goto error;
    }

    n = PyLong_AsLong(num);
    if (n == -1 && PyErr_Occurred())
        goto error;

    arr = (pthread_t *)PyMem_RawCalloc(n, sizeof(pthread_t));
    if (!arr)
        goto error;

    a.sec = sec;
    a.py_callback = py_callback;
    for (i = 0; i < n; i++) {

```

(continues on next page)

(continued from previous page)

```

    if (pthread_create(&arr[i], NULL, foo_thread, &a)) {
        PyErr_SetString(PyExc_TypeError, "create a thread failed");
        goto error;
    }
}

for (i = 0; i < n; i++) {
    if (pthread_join(arr[i], NULL)) {
        PyErr_SetString(PyExc_TypeError, "thread join failed");
        goto error;
    }
}
Py_XINCREF(Py_None);
rv = Py_None;
error:
    PyMem_RawFree(arr);
    Py_XDECREF(sec);
    Py_XDECREF(num);
    Py_XDECREF(py_callback);
    // restore GIL
    Py_END_ALLOW_THREADS
    return rv;
}

static PyMethodDef methods[] = {
    {"foo", (PyCFunction)foo, METH_VARARGS, NULL},
    {NULL, NULL, 0, NULL}
};

static struct PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "foo", NULL, -1, methods
};

PyMODINIT_FUNC PyInit_foo(void)
{
    return PyModule_Create(&module);
}

```

output:

```

$ python setup.py -q build
$ python setup.py -q install
$ pyton -q
>>> import foo
>>> from datetime import datetime
>>> def cb(s):
...     now = datetime.now()
...     print(f'{now}: {s}')
...
>>> foo.foo(3, 1, cb)
2018-11-05 09:33:50.642543: Awesome Python!
2018-11-05 09:33:50.642634: Awesome Python!

```

(continues on next page)

(continued from previous page)

```
2018-11-05 09:33:50.642672: Awesome Python!
```

If threads are created from C/C++, those threads do not hold the GIL. Without acquiring the GIL, the interpreter cannot access Python functions safely. For example

```
void *
foo_thread(void *args)
{
    ...
    // without acquiring the GIL
    rv = PyObject_CallFunction(py_callback, "s", "Awesome Python!");
    Py_XDECREF(rv);
    return NULL;
}
```

output:

```
>>> import foo
>>> from datetime import datetime
>>> def cb(s):
...     now = datetime.now()
...     print(f"{now}: {s}")
...
>>> foo.foo(1, 1, cb)
[2] 8590 segmentation fault python -q
```

Warning: In order to call python function safely, we can simply warp **Python Functions** between PyGILState_Ensure and PyGILState_Release in C extension code.

```
PyGILState_STATE state = PyGILState_Ensure();
// Perform Python actions
result = PyObject_CallFunction(callback)
// Error handling
PyGILState_Release(state);
```

3.10.7 Get Reference Count

```
#include <Python.h>

static PyObject *
getrefcount(PyObject *self, PyObject *a)
{
    return PyLong_FromSsize_t(Py_REFCNT(a));
}

static PyMethodDef methods[] = {
    {"getrefcount", (PyCFunction)getrefcount, METH_O, NULL},
    {NULL, NULL, 0, NULL}
};
```

(continues on next page)

(continued from previous page)

```
static struct PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "foo", NULL, -1, methods
};

PyMODINIT_FUNC PyInit_foo(void)
{
    return PyModule_Create(&module);
}
```

output:

```
$ python setup.py -q build
$ python setup.py -q install
$ python -q
>>> import sys
>>> import foo
>>> l = [1, 2, 3]
>>> sys.getrefcount(l[0])
104
>>> foo.getrefcount(l[0])
104
>>> i = l[0]
>>> sys.getrefcount(l[0])
105
>>> foo.getrefcount(l[0])
105
```

3.10.8 Parse Arguments

```
#include <Python.h>

static PyObject *
foo(PyObject *self)
{
    Py_RETURN_NONE;
}

static PyObject *
bar(PyObject *self, PyObject *arg)
{
    return Py_BuildValue("O", arg);
}

static PyObject *
baz(PyObject *self, PyObject *args)
{
    PyObject *x = NULL, *y = NULL;
    if (!PyArg_ParseTuple(args, "OO", &x, &y)) {
        return NULL;
    }
}
```

(continues on next page)

(continued from previous page)

```

    }
    return Py_BuildValue("OO", x, y);
}

static PyObject *
qux(PyObject *self, PyObject *args, PyObject *kwargs)
{
    static char *keywords[] = {"x", "y", NULL};
    PyObject *x = NULL, *y = NULL;
    if (!PyArg_ParseTupleAndKeywords(args, kwargs,
                                     "O|O", keywords,
                                     &x, &y))
    {
        return NULL;
    }
    if (!y) {
        y = Py_None;
    }
    return Py_BuildValue("OO", x, y);
}

static PyMethodDef methods[] = {
    {"foo", (PyCFunction)foo, METH_NOARGS, NULL},
    {"bar", (PyCFunction)bar, METH_O, NULL},
    {"baz", (PyCFunction)baz, METH_VARARGS, NULL},
    {"qux", (PyCFunction)qux, METH_VARARGS | METH_KEYWORDS, NULL},
    {NULL, NULL, 0, NULL}
};

static struct PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "foo", NULL, -1, methods
};

PyMODINIT_FUNC PyInit_foo(void)
{
    return PyModule_Create(&module);
}

```

output:

```

$ python setup.py -q build
$ python setup.py -q install
$ python -q
>>> import foo
>>> foo.foo()
>>> foo.bar(3.7)
3.7
>>> foo.baz(3, 7)
(3, 7)
>>> foo.qux(3, y=7)
(3, 7)
>>> foo.qux(x=3, y=7)

```

(continues on next page)

(continued from previous page)

```
(3, 7)
>>> foo.qux(x=3)
(3, None)
```

3.10.9 Calling Python Functions

```
#include <Python.h>

static PyObject *
foo(PyObject *self, PyObject *args)
{
    PyObject *py_callback = NULL;
    PyObject *rv = NULL;

    if (!PyArg_ParseTuple(args, "O:callback", &py_callback))
        return NULL;

    if (!PyCallable_Check(py_callback)) {
        PyErr_SetString(PyExc_TypeError, "should be callable");
        return NULL;
    }

    // Make sure we own the GIL
    PyGILState_STATE state = PyGILState_Ensure();
    // similar to py_callback("Awesome Python!")
    rv = PyObject_CallFunction(py_callback, "s", "Awesome Python!");
    // Restore previous GIL state
    PyGILState_Release(state);
    return rv;
}

static PyMethodDef methods[] = {
    {"foo", (PyCFunction)foo, METH_VARARGS, NULL},
    {NULL, NULL, 0, NULL}
};

static struct PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "foo", NULL, -1, methods
};

PyMODINIT_FUNC PyInit_foo(void)
{
    return PyModule_Create(&module);
}
```

output:

```
$ python setup.py -q build
$ python setup.py -q install
$ python -c "import foo; foo.foo(print)"
Awesome Python!
```

3.10.10 Raise Exception

```
#include <Python.h>

PyDoc_STRVAR(doc_mod, "Module document\n");
PyDoc_STRVAR(doc_foo, "foo() -> None\n\nFoo doc");

static PyObject*
foo(PyObject* self)
{
    // raise NotImplementedError
    PyErr_SetString(PyExc_NotImplementedError, "Not implemented");
    return NULL;
}

static PyMethodDef methods[] = {
    {"foo", (PyCFunction)foo, METH_NOARGS, doc_foo},
    {NULL, NULL, 0, NULL}
};

static struct PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "Foo", doc_mod, -1, methods
};

PyMODINIT_FUNC PyInit_foo(void)
{
    return PyModule_Create(&module);
}
```

output:

```
$ python setup.py -q build
$ python setup.py -q install
$ python -c "import foo; foo.foo(print)"
$ python -c "import foo; foo.foo()"
Traceback (most recent call last):
  File "<string>", line 1, in <module>
NotImplementedError: Not implemented
```

3.10.11 Customize Exception

```
#include <stdio.h>
#include <Python.h>

static PyObject *FooError;

PyDoc_STRVAR(doc_foo, "foo() -> void\n\n"
    "Equal to the following example:\n\n"
    "def foo():\n"
    "    raise FooError(\"Raise exception in C\")"
);
```

(continues on next page)

(continued from previous page)

```

static PyObject *
foo(PyObject *self __attribute__((unused)))
{
    PyErr_SetString(FooError, "Raise exception in C");
    return NULL;
}

static PyMethodDef methods[] = {
    {"foo", (PyCFunction)foo, METH_NOARGS, doc_foo},
    {NULL, NULL, 0, NULL}
};

static struct PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "foo", "doc", -1, methods
};

PyMODINIT_FUNC PyInit_foo(void)
{
    PyObject *m = NULL;
    m = PyModule_Create(&module);
    if (!m) return NULL;

    FooError = PyErr_NewException("foo.FooError", NULL, NULL);
    Py_INCREF(FooError);
    PyModule_AddObject(m, "FooError", FooError);
    return m;
}

```

output:

```

$ python setup.py -q build
$ python setup.py -q install
$ python -c "import foo; foo.foo()"
Traceback (most recent call last):
  File "<string>", line 1, in <module>
foo.FooError: Raise exception in C

```

3.10.12 Iterate a List

```

#include <Python.h>

#define PY_PRINTF(o) \
    PyObject_Print(o, stdout, 0); printf("\n");

static PyObject *
iter_list(PyObject *self, PyObject *args)
{
    PyObject *list = NULL, *item = NULL, *iter = NULL;
    PyObject *result = NULL;

```

(continues on next page)

(continued from previous page)

```

    if (!PyArg_ParseTuple(args, "O", &list))
        goto error;

    if (!PyList_Check(list))
        goto error;

    // Get iterator
    iter = PyObject_GetIter(list);
    if (!iter)
        goto error;

    // for i in arr: print(i)
    while ((item = PyIter_Next(iter)) != NULL) {
        PY_PRINTF(item);
        Py_XDECREF(item);
    }

    Py_XINCREf(Py_None);
    result = Py_None;
error:
    Py_XDECREF(iter);
    return result;
}

static PyMethodDef methods[] = {
    {"iter_list", (PyCFunction)iter_list, METH_VARARGS, NULL},
    {NULL, NULL, 0, NULL}
};

static struct PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "foo", NULL, -1, methods
};

PyMODINIT_FUNC PyInit_foo(void)
{
    return PyModule_Create(&module);
}

```

output:

```

$ python setup.py -q build
$ python setup.py -q install
$ python -c "import foo; foo.iter_list([1,2,3])"
1
2
3

```

3.10.13 Iterate a Dictionary

```
#include <Python.h>

#define PY_PRINTF(o) \
    PyObject_Print(o, stdout, 0); printf("\n");

static PyObject *
iter_dict(PyObject *self, PyObject *args)
{
    PyObject *dict = NULL;
    PyObject *key = NULL, *val = NULL;
    PyObject *o = NULL, *result = NULL;
    Py_ssize_t pos = 0;

    if (!PyArg_ParseTuple(args, "O", &dict))
        goto error;

    // for k, v in d.items(): print(f"{k}, {v}")
    while (PyDict_Next(dict, &pos, &key, &val)) {
        o = PyUnicode_FromFormat("(%S, %S)", key, val);
        if (!o) continue;
        PY_PRINTF(o);
        Py_XDECREF(o);
    }

    Py_INCREF(Py_None);
    result = Py_None;
error:
    return result;
}

static PyMethodDef methods[] = {
    {"iter_dict", (PyCFunction)iter_dict, METH_VARARGS, NULL},
    {NULL, NULL, 0, NULL}
};

static struct PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "foo", NULL, -1, methods
};

PyMODINIT_FUNC PyInit_foo(void)
{
    return PyModule_Create(&module);
}
```

output:

```
$ python setup.py -q build
$ python setup.py -q install
$ python -c "import foo; foo.iter_dict({'k': 'v'})"
'(k, v)'
```

3.10.14 Simple Class

```
#include <Python.h>

typedef struct {
    PyObject_HEAD
} FooObject;

/* class Foo(object): pass */

static PyTypeObject FooType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    .tp_name = "foo.Foo",
    .tp_doc = "Foo objects",
    .tp_basicsize = sizeof(FooObject),
    .tp_itemsize = 0,
    .tp_flags = Py_TPFLAGS_DEFAULT,
    .tp_new = PyType_GenericNew
};

static PyModuleDef module = {
    PyModuleDef_HEAD_INIT,
    .m_name = "foo",
    .m_doc = "module foo",
    .m_size = -1
};

PyMODINIT_FUNC
PyInit_foo(void)
{
    PyObject *m = NULL;
    if (PyType_Ready(&FooType) < 0)
        return NULL;
    if ((m = PyModule_Create(&module)) == NULL)
        return NULL;
    Py_XINCREF(&FooType);
    PyModule_AddObject(m, "Foo", (PyObject *) &FooType);
    return m;
}
```

output:

```
$ python setup.py -q build
$ python setup.py -q install
$ python -q
>>> import foo
>>> print(type(foo.Foo))
<class 'type'>
>>> o = foo.Foo()
>>> print(type(o))
<class 'foo.Foo'>
>>> class Foo(object): ...
...
```

(continues on next page)

(continued from previous page)

```
>>> print(type(Foo))
<class 'type'>
>>> o = Foo()
>>> print(type(o))
<class '__main__.Foo'>
```

3.10.15 Simple Class with Members and Methods

```
#include <Python.h>
#include <structmember.h>

/*
 * class Foo:
 *     def __new__(cls, *a, **kw):
 *         foo_obj = object.__new__(cls)
 *         foo_obj.foo = ""
 *         foo_obj.bar = ""
 *         return foo_obj
 *
 *     def __init__(self, foo, bar):
 *         self.foo = foo
 *         self.bar = bar
 *
 *     def fib(self, n):
 *         if n < 2:
 *             return n
 *         return self.fib(n - 1) + self.fib(n - 2)
 */

typedef struct {
    PyObject_HEAD
    PyObject *foo;
    PyObject *bar;
} FooObject;

static void
Foo_dealloc(FooObject *self)
{
    Py_XDECREF(self->foo);
    Py_XDECREF(self->bar);
    Py_TYPE(self)->tp_free((PyObject *) self);
}

static PyObject *
Foo_new(PyTypeObject *type, PyObject *args, PyObject *kw)
{
    int rc = -1;
    FooObject *self = NULL;
    self = (FooObject *) type->tp_alloc(type, 0);
```

(continues on next page)

(continued from previous page)

```

    if (!self) goto error;

    /* allocate attributes */
    self->foo = PyUnicode_FromString("");
    if (self->foo == NULL) goto error;

    self->bar = PyUnicode_FromString("");
    if (self->bar == NULL) goto error;

    rc = 0;
error:
    if (rc < 0) {
        Py_XDECREF(self->foo);
        Py_XDECREF(self->bar);
        Py_DECREF(self);
    }
    return (PyObject *) self;
}

static int
Foo_init(FooObject *self, PyObject *args, PyObject *kw)
{
    int rc = -1;
    static char *keywords[] = {"foo", "bar", NULL};
    PyObject *foo = NULL, *bar = NULL, *ptr = NULL;

    if (!PyArg_ParseTupleAndKeywords(args, kw,
                                     "|00", keywords,
                                     &foo, &bar))
    {
        goto error;
    }

    if (foo) {
        ptr = self->foo;
        Py_INCREF(foo);
        self->foo = foo;
        Py_XDECREF(ptr);
    }

    if (bar) {
        ptr = self->bar;
        Py_INCREF(bar);
        self->bar = bar;
        Py_XDECREF(ptr);
    }
    rc = 0;
error:
    return rc;
}

static unsigned long

```

(continues on next page)

(continued from previous page)

```

fib(unsigned long n)
{
    if (n < 2) return n;
    return fib(n - 1) + fib(n - 2);
}

static PyObject *
Foo_fib(PyObject *self, PyObject *args)
{
    unsigned long n = 0;
    if (!PyArg_ParseTuple(args, "k", &n)) return NULL;
    return PyLong_FromUnsignedLong(fib(n));
}

static PyMemberDef Foo_members[] = {
    {"foo", T_OBJECT_EX, offsetof(FooObject, foo), 0, NULL},
    {"bar", T_OBJECT_EX, offsetof(FooObject, bar), 0, NULL}
};

static PyMethodDef Foo_methods[] = {
    {"fib", (PyCFunction)Foo_fib, METH_VARARGS | METH_KEYWORDS, NULL},
    {NULL, NULL, 0, NULL}
};

static PyTypeObject FooType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    .tp_name = "foo.Foo",
    .tp_doc = "Foo objects",
    .tp_basicsize = sizeof(FooObject),
    .tp_itemsize = 0,
    .tp_flags = Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE,
    .tp_new = Foo_new,
    .tp_init = (initproc) Foo_init,
    .tp_dealloc = (destructor) Foo_dealloc,
    .tp_members = Foo_members,
    .tp_methods = Foo_methods
};

static PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "foo", NULL, -1, NULL
};

PyMODINIT_FUNC
PyInit_foo(void)
{
    PyObject *m = NULL;
    if (PyType_Ready(&FooType) < 0)
        return NULL;
    if ((m = PyModule_Create(&module)) == NULL)
        return NULL;
    Py_INCREF(&FooType);
    PyModule_AddObject(m, "Foo", (PyObject *) &FooType);
}

```

(continues on next page)

(continued from previous page)

```
    return m;
}
```

output:

```
$ python setup.py -q build
$ python setup.py -q install
$ python -q
>>> import foo
>>> o = foo.Foo('foo', 'bar')
>>> o.foo
'foo'
>>> o.bar
'bar'
>>> o.fib(10)
55
```

3.10.16 Simple Class with Getter and Setter

```
#include <Python.h>

/*
 * class Foo:
 *     def __new__(cls, *a, **kw):
 *         foo_obj = object.__new__(cls)
 *         foo_obj._foo = ""
 *         return foo_obj
 *
 *     def __init__(self, foo=None):
 *         if foo and isinstance(foo, 'str'):
 *             self._foo = foo
 *
 *     @property
 *     def foo(self):
 *         return self._foo
 *
 *     @foo.setter
 *     def foo(self, value):
 *         if not value or not isinstance(value, str):
 *             raise TypeError("value should be unicode")
 *         self._foo = value
 */

typedef struct {
    PyObject_HEAD
    PyObject *foo;
} FooObject;

static void
Foo_dealloc(FooObject *self)
```

(continues on next page)

(continued from previous page)

```

{
    Py_XDECREF(self->foo);
    Py_TYPE(self)->tp_free((PyObject *) self);
}

static PyObject *
Foo_new(PyTypeObject *type, PyObject *args, PyObject *kw)
{
    int rc = -1;
    FooObject *self = NULL;
    self = (FooObject *) type->tp_alloc(type, 0);

    if (!self) goto error;

    /* allocate attributes */
    self->foo = PyUnicode_FromString("");
    if (self->foo == NULL) goto error;

    rc = 0;
error:
    if (rc < 0) {
        Py_XDECREF(self->foo);
        Py_XDECREF(self);
    }
    return (PyObject *) self;
}

static int
Foo_init(FooObject *self, PyObject *args, PyObject *kw)
{
    int rc = -1;
    static char *keywords[] = {"foo", NULL};
    PyObject *foo = NULL, *ptr = NULL;

    if (!PyArg_ParseTupleAndKeywords(args, kw,
                                     "|O", keywords,
                                     &foo))
    {
        goto error;
    }

    if (foo && PyUnicode_Check(foo)) {
        ptr = self->foo;
        Py_INCREF(foo);
        self->foo = foo;
        Py_XDECREF(ptr);
    }

    rc = 0;
error:
    return rc;
}

```

(continues on next page)

(continued from previous page)

```

static PyObject *
Foo_getfoo(FooObject *self, void *closure)
{
    Py_INCREF(self->foo);
    return self->foo;
}

static int
Foo_setfoo(FooObject *self, PyObject *value, void *closure)
{
    int rc = -1;

    if (!value || !PyUnicode_Check(value)) {
        PyErr_SetString(PyExc_TypeError, "value should be unicode");
        goto error;
    }
    Py_INCREF(value);
    Py_XDECREF(self->foo);
    self->foo = value;
    rc = 0;
error:
    return rc;
}

static PyGetSetDef Foo_getsetters[] = {
    {"foo", (getter)Foo_getfoo, (setter)Foo_setfoo}
};

static PyTypeObject FooType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    .tp_name = "foo.Foo",
    .tp_doc = "Foo objects",
    .tp_basicsize = sizeof(FooObject),
    .tp_itemsize = 0,
    .tp_flags = Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE,
    .tp_new = Foo_new,
    .tp_init = (initproc) Foo_init,
    .tp_dealloc = (destructor) Foo_dealloc,
    .tp_getset = Foo_getsetters,
};

static PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "foo", NULL, -1, NULL
};

PyMODINIT_FUNC
PyInit_foo(void)
{
    PyObject *m = NULL;
    if (PyType_Ready(&FooType) < 0)
        return NULL;

```

(continues on next page)

(continued from previous page)

```

    if ((m = PyModule_Create(&module)) == NULL)
        return NULL;
    Py_INCREF(&FooType);
    PyModule_AddObject(m, "Foo", (PyObject *) &FooType);
    return m;
}

```

output:

```

$ python setup.py -q build
$ python setup.py -q install
$ python -q
>>> import foo
>>> o = foo.Foo()
>>> o.foo
''
>>> o.foo = "foo"
>>> o.foo
'foo'
>>> o.foo = None
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: value should be unicode

```

3.10.17 Inherit from Other Class

```

#include <Python.h>
#include <structmember.h>

/*
 * class Foo:
 *     def __new__(cls, *a, **kw):
 *         foo_obj = object.__new__(cls)
 *         foo_obj.foo = ""
 *         return foo_obj
 *
 *     def __init__(self, foo):
 *         self.foo = foo
 *
 *     def fib(self, n):
 *         if n < 2:
 *             return n
 *         return self.fib(n - 1) + self.fib(n - 2)
 */

/* FooObject */

typedef struct {
    PyObject_HEAD
    PyObject *foo;
}

```

(continues on next page)

(continued from previous page)

```

} FooObject;

static void
Foo_dealloc(FooObject *self)
{
    Py_XDECREF(self->foo);
    Py_TYPE(self)->tp_free((PyObject *) self);
}

static PyObject *
Foo_new(PyTypeObject *type, PyObject *args, PyObject *kw)
{
    int rc = -1;
    FooObject *self = NULL;
    self = (FooObject *) type->tp_alloc(type, 0);

    if (!self) goto error;

    /* allocate attributes */
    self->foo = PyUnicode_FromString("");
    if (self->foo == NULL) goto error;

    rc = 0;
error:
    if (rc < 0) {
        Py_XDECREF(self->foo);
        Py_XDECREF(self);
    }
    return (PyObject *) self;
}

static int
Foo_init(FooObject *self, PyObject *args, PyObject *kw)
{
    int rc = -1;
    static char *keywords[] = {"foo", NULL};
    PyObject *foo = NULL, *ptr = NULL;

    if (!PyArg_ParseTupleAndKeywords(args, kw, "|O", keywords, &foo)) {
        goto error;
    }

    if (foo) {
        ptr = self->foo;
        Py_INCREF(foo);
        self->foo = foo;
        Py_XDECREF(ptr);
    }
    rc = 0;
error:
    return rc;
}

```

(continues on next page)

(continued from previous page)

```

static unsigned long
fib(unsigned long n)
{
    if (n < 2) return n;
    return fib(n - 1) + fib(n - 2);
}

static PyObject *
Foo_fib(PyObject *self, PyObject *args)
{
    unsigned long n = 0;
    if (!PyArg_ParseTuple(args, "k", &n)) return NULL;
    return PyLong_FromUnsignedLong(fib(n));
}

static PyMemberDef Foo_members[] = {
    {"foo", T_OBJECT_EX, offsetof(FooObject, foo), 0, NULL}
};

static PyMethodDef Foo_methods[] = {
    {"fib", (PyCFunction)Foo_fib, METH_VARARGS | METH_KEYWORDS, NULL},
    {NULL, NULL, 0, NULL}
};

static PyTypeObject FooType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    .tp_name = "foo.Foo",
    .tp_doc = "Foo objects",
    .tp_basicsize = sizeof(FooObject),
    .tp_itemsize = 0,
    .tp_flags = Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE,
    .tp_new = Foo_new,
    .tp_init = (initproc) Foo_init,
    .tp_dealloc = (destructor) Foo_dealloc,
    .tp_members = Foo_members,
    .tp_methods = Foo_methods
};

/*
 * class Bar(Foo):
 *     def __init__(self, bar):
 *         super().__init__(bar)
 *
 *     def gcd(self, a, b):
 *         while b:
 *             a, b = b, a % b
 *         return a
 */

/* BarObject */

```

(continues on next page)

(continued from previous page)

```

typedef struct {
    FooObject super;
} BarObject;

static unsigned long
gcd(unsigned long a, unsigned long b)
{
    unsigned long t = 0;
    while (b) {
        t = b;
        b = a % b;
        a = t;
    }
    return a;
}

static int
Bar_init(FooObject *self, PyObject *args, PyObject *kw)
{
    return FooType.tp_init((PyObject *) self, args, kw);
}

static PyObject *
Bar_gcd(BarObject *self, PyObject *args)
{
    unsigned long a = 0, b = 0;
    if (!PyArg_ParseTuple(args, "kk", &a, &b)) return NULL;
    return PyLong_FromUnsignedLong(gcd(a, b));
}

static PyMethodDef Bar_methods[] = {
    {"gcd", (PyCFunction)Bar_gcd, METH_VARARGS, NULL},
    {NULL, NULL, 0, NULL}
};

static PyTypeObject BarType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    .tp_name = "foo.Bar",
    .tp_doc = "Bar objects",
    .tp_basicsize = sizeof(BarObject),
    .tp_itemsize = 0,
    .tp_flags = Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE,
    .tp_base = &FooType,
    .tp_init = (initproc) Bar_init,
    .tp_methods = Bar_methods
};

/* Module */

static PyModuleDef module = {
    PyModuleDef_HEAD_INIT, "foo", NULL, -1, NULL
};

```

(continues on next page)

(continued from previous page)

```

PyMODINIT_FUNC
PyInit_foo(void)
{
    PyObject *m = NULL;
    if (PyType_Ready(&FooType) < 0)
        return NULL;
    if (PyType_Ready(&BarType) < 0)
        return NULL;
    if ((m = PyModule_Create(&module)) == NULL)
        return NULL;

    Py_XINCREf(&FooType);
    Py_XINCREf(&BarType);
    PyModule_AddObject(m, "Foo", (PyObject *) &FooType);
    PyModule_AddObject(m, "Bar", (PyObject *) &BarType);
    return m;
}

```

output:

```

$ python setup.py -q build
$ python setup.py -q install
$ python -q
>>> import foo
>>> bar = foo.Bar('bar')
>>> bar.foo
'bar'
>>> bar.fib(10)
55
>>> bar.gcd(3, 7)
1

```

3.10.18 Run a Python Command

```

#include <stdio.h>
#include <Python.h>

int
main(int argc, char *argv[])
{
    int rc = -1;
    Py_Initialize();
    rc = PyRun_SimpleString(argv[1]);
    Py_Finalize();
    return rc;
}

```

output:

```
$ clang `python3-config --cflags` -c foo.c -o foo.o
$ clang `python3-config --ldflags` foo.o -o foo
$ ./foo "print('Hello Python')"
Hello Python
```

3.10.19 Run a Python File

```
#include <stdio.h>
#include <Python.h>

int
main(int argc, char *argv[])
{
    int rc = -1, i = 0;
    wchar_t **argv_copy = NULL;
    const char *filename = NULL;
    FILE *fp = NULL;
    PyCompilerFlags cf = {.cf_flags = 0};

    filename = argv[1];
    fp = fopen(filename, "r");
    if (!fp)
        goto error;

    // copy argv
    argv_copy = PyMem_RawMalloc(sizeof(wchar_t*) * argc);
    if (!argv_copy)
        goto error;

    for (i = 0; i < argc; i++) {
        argv_copy[i] = Py_DecodeLocale(argv[i], NULL);
        if (argv_copy[i]) continue;
        fprintf(stderr, "Unable to decode the argument");
        goto error;
    }

    Py_Initialize();
    Py_SetProgramName(argv_copy[0]);
    PySys_SetArgv(argc, argv_copy);
    rc = PyRun_AnyFileExFlags(fp, filename, 0, &cf);

error:
    if (argv_copy) {
        for (i = 0; i < argc; i++)
            PyMem_RawFree(argv_copy[i]);
        PyMem_RawFree(argv_copy);
    }
    if (fp) fclose(fp);
    Py_Finalize();
    return rc;
}
```

output:

```
$ clang `python3-config --cflags` -c foo.c -o foo.o
$ clang `python3-config --ldflags` foo.o -o foo
$ echo "import sys; print(sys.argv)" > foo.py
$ ./foo foo.py arg1 arg2 arg3
['./foo', 'foo.py', 'arg1', 'arg2', 'arg3']
```

3.10.20 Import a Python Module

```
#include <stdio.h>
#include <Python.h>

#define PYOBJECT_CHECK(obj, label) \
    if (!obj) { \
        PyErr_Print(); \
        goto label; \
    }

int
main(int argc, char *argv[])
{
    int rc = -1;
    wchar_t *program = NULL;
    PyObject *json_module = NULL, *json_dict = NULL;
    PyObject *json_dumps = NULL;
    PyObject *dict = NULL;
    PyObject *result = NULL;

    program = Py_DecodeLocale(argv[0], NULL);
    if (!program) {
        fprintf(stderr, "unable to decode the program name");
        goto error;
    }

    Py_SetProgramName(program);
    Py_Initialize();

    // import json
    json_module = PyImport_ImportModule("json");
    PYOBJECT_CHECK(json_module, error);

    // json_dict = json.__dict__
    json_dict = PyModule_GetDict(json_module);
    PYOBJECT_CHECK(json_dict, error);

    // json_dumps = json.__dict__['dumps']
    json_dumps = PyDict_GetItemString(json_dict, "dumps");
    PYOBJECT_CHECK(json_dumps, error);

    // dict = {'foo': 'Foo', 'bar': 123}
    dict = Py_BuildValue("{sssi}", "foo", "Foo", "bar", 123);
```

(continues on next page)

(continued from previous page)

```

PYOBJECT_CHECK(dict, error);

// result = json.dumps(dict)
result = PyObject_CallObject(json_dumps, dict);
PYOBJECT_CHECK(result, error);
PyObject_Print(result, stdout, 0);
printf("\n");
rc = 0;

error:
    Py_XDECREF(result);
    Py_XDECREF(dict);
    Py_XDECREF(json_dumps);
    Py_XDECREF(json_dict);
    Py_XDECREF(json_module);

    PyMem_RawFree(program);
    Py_Finalize();
    return rc;
}

```

output:

```

$ clang `python3-config --cflags` -c foo.c -o foo.o
$ clang `python3-config --ldflags` foo.o -o foo
$ ./foo
{'foo': "Foo", "bar": 123}

```

3.10.21 Import everything of a Module

```

#include <stdio.h>
#include <Python.h>

#define PYOBJECT_CHECK(obj, label) \
    if (!obj) { \
        PyErr_Print(); \
        goto label; \
    }

int
main(int argc, char *argv[])
{
    int rc = -1;
    wchar_t *program = NULL;
    PyObject *main_module = NULL, *main_dict = NULL;
    PyObject *uname = NULL;
    PyObject *sysname = NULL;
    PyObject *result = NULL;

```

(continues on next page)

(continued from previous page)

```

program = Py_DecodeLocale(argv[0], NULL);
if (!program) {
    fprintf(stderr, "unable to decode the program name");
    goto error;
}

Py_SetProgramName(program);
Py_Initialize();

// import __main__
main_module = PyImport_ImportModule("__main__");
PYOBJECT_CHECK(main_module, error);

// main_dict = __main__.__dict__
main_dict = PyModule_GetDict(main_module);
PYOBJECT_CHECK(main_dict, error);

// from os import *
result = PyRun_String("from os import *",
                      Py_file_input,
                      main_dict,
                      main_dict);
PYOBJECT_CHECK(result, error);
Py_XDECREF(result);
Py_XDECREF(main_dict);

// uname = __main__.__dict__['uname']
main_dict = PyModule_GetDict(main_module);
PYOBJECT_CHECK(main_dict, error);

// result = uname()
uname = PyDict_GetItemString(main_dict, "uname");
PYOBJECT_CHECK(uname, error);
result = PyObject_CallObject(uname, NULL);
PYOBJECT_CHECK(result, error);

// sysname = result.sysname
sysname = PyObject_GetAttrString(result, "sysname");
PYOBJECT_CHECK(sysname, error);
PyObject_Print(sysname, stdout, 0);
printf("\n");

rc = 0;
error:
    Py_XDECREF(sysname);
    Py_XDECREF(result);
    Py_XDECREF(uname);
    Py_XDECREF(main_dict);
    Py_XDECREF(main_module);

    PyMem_RawFree(program);
    Py_Finalize();

```

(continues on next page)

(continued from previous page)

```

    return rc;
}

```

output:

```

$ clang `python3-config --cflags` -c foo.c -o foo.o
$ clang `python3-config --ldflags` foo.o -o foo
$ ./foo
'Darwin'

```

3.10.22 Access Attributes

```

#include <stdio.h>
#include <Python.h>

#define PYOBJECT_CHECK(obj, label) \
    if (!obj) { \
        PyErr_Print(); \
        goto label; \
    }

int
main(int argc, char *argv[])
{
    int rc = -1;
    wchar_t *program = NULL;
    PyObject *json_module = NULL;
    PyObject *json_dumps = NULL;
    PyObject *dict = NULL;
    PyObject *result = NULL;

    program = Py_DecodeLocale(argv[0], NULL);
    if (!program) {
        fprintf(stderr, "unable to decode the program name");
        goto error;
    }

    Py_SetProgramName(program);
    Py_Initialize();

    // import json
    json_module = PyImport_ImportModule("json");
    PYOBJECT_CHECK(json_module, error);

    // json_dumps = json.dumps
    json_dumps = PyObject_GetAttrString(json_module, "dumps");
    PYOBJECT_CHECK(json_dumps, error);

    // dict = {'foo': 'Foo', 'bar': 123}
    dict = Py_BuildValue("{sssi}", "foo", "Foo", "bar", 123);

```

(continues on next page)