The Hidden Power of the Python Runtime

Elizaveta Shashkova
EuroPython 2020
Online

About Me

- Software Developer at JetBrains, PyCharm IDE
- St Petersburg, Russia
- @lisa_shashkova
- Discord: #talk-python-runtime

The hidden power?

The hidden power?

You already use it every day

Test Frameworks

- unittest
- pytest

AssertionError

- unittest

```
Traceback (most recent call last):
  File “/file.py”, line 8, in test_value
    assert a == 2, "Wrong value!"
AssertionError: Wrong value!
```

AssertionError

- unittest

```
Traceback (most recent call last):
  File “/file.py”, line 8, in test_value
    assert a == 2, "Wrong value!"
AssertionError: Wrong value!
```

- pytest

```
E       AssertionError: Wrong value!
E       assert 1 == 2
```


@lisa_shashkova

Contents

- Python Runtime
- Getting Runtime Information
- Development Tools

Contents

- Python Runtime
- Getting Runtime Information
- Development Tools

Python Objects

- Created explicitly
    - variables, functions, classes, modules

Python Objects

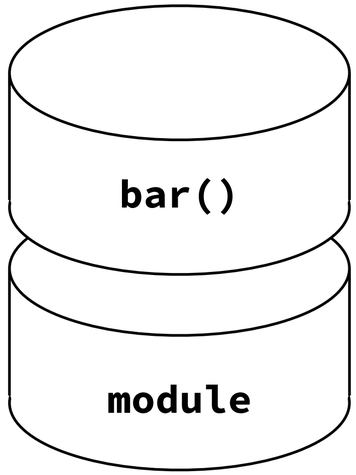
- Created explicitly
    - variables, functions, classes, modules
- Created implicitly
    - **`stack frame`**, code object

Stack Frame

- Represents a program scope
- Information about execution state:
    - Corresponding code object
    - Local and global variables
    - Other data

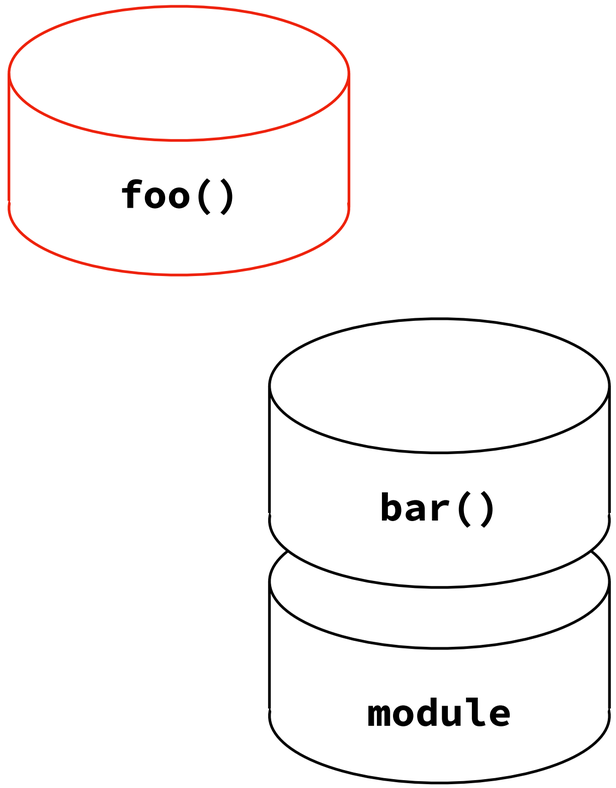
Stack Frame

```
 1 def foo(n):
 2     n = n - 1
 3     return n
 4
 5
 6 def bar(k):
 7     res = foo(k)
 8     return res * 2
 9
10
11 print(bar(1))
```



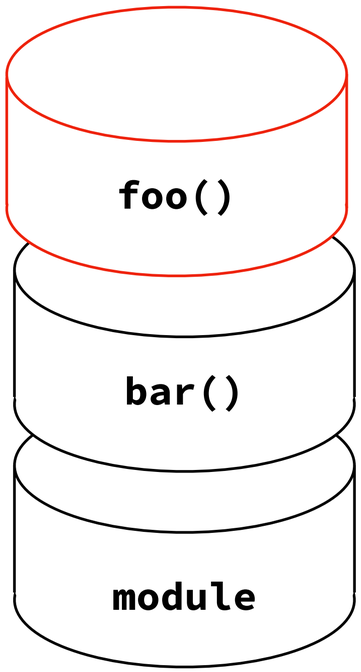
Stack Frame

```
 1 def foo(n):
 2     n = n - 1
 3     return n
 4
 5
 6 def bar(k):
 7     res = foo(k)
 8     return res * 2
 9
10
11 print(bar(1))
```



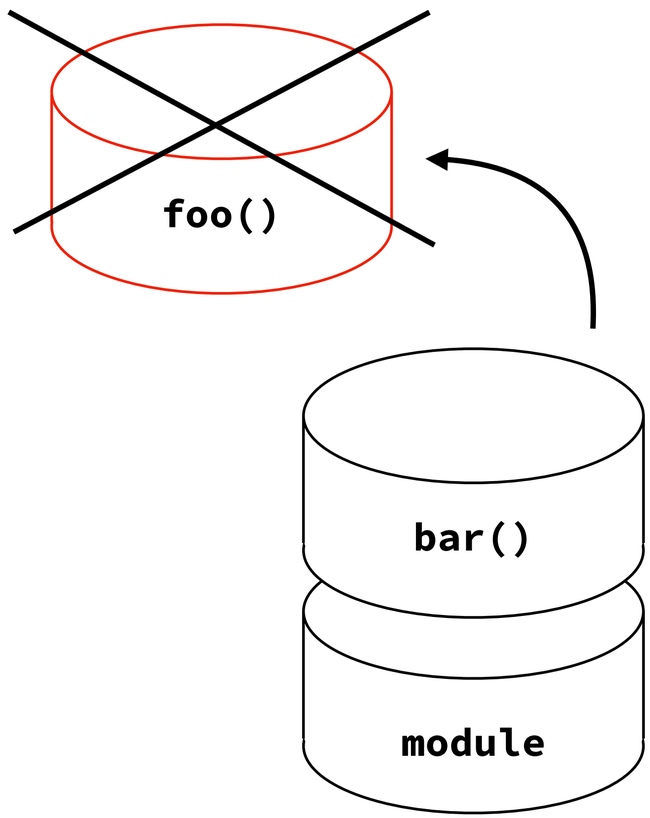
Stack Frame

```
 1 def foo(n):
 2     n = n - 1
 3     return n
 4
 5
 6 def bar(k):
 7     res = foo(k)
 8     return res * 2
 9
10
11 print(bar(1))
```



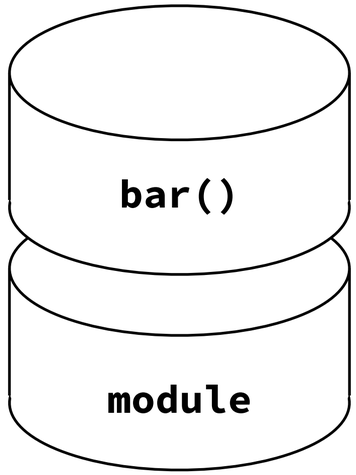
Stack Frame

```
 1 def foo(n):
 2     n = n - 1
 3     return n
 4
 5
 6 def bar(k):
 7     res = foo(k)
 8     return res * 2
 9
10
11 print(bar(1))
```



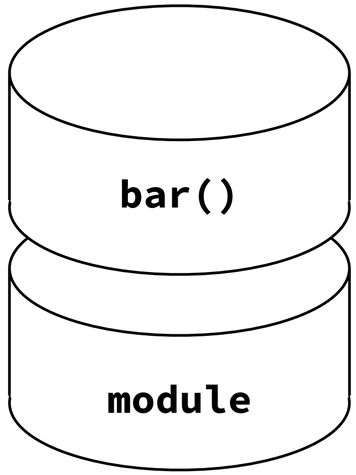
Stack Frame

```
 1 def foo(n):
 2     n = n - 1
 3     return n
 4
 5
 6 def bar(k):
 7     res = foo(k)
 8     return res * 2
 9
10
11 print(bar(1))
```



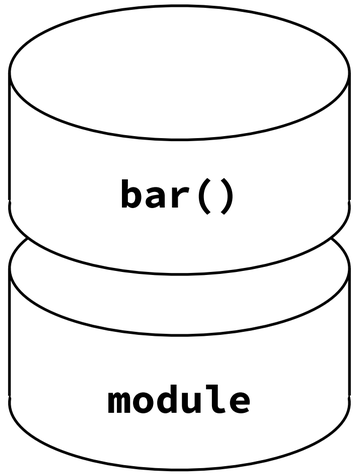
Python Power

- Available out of the box



Python Power

- Available out of the box
- Stack frame objects access



Contents

- Python Runtime
- Getting Runtime Information
- Development Tools

Python Stack Frame

- **`sys._getframe([depth])`**
- **`depth`** - number of calls below the top
- 0 - current frame

Frame Object

Frame Object: Variables

- Local variables
  - **`frame.f_locals`**

Frame Object: Variables

- Local variables
  - **`frame.f_locals`**
- Global variables
  - **`frame.f_globals`**

Frame Object: Variables

- Local variables
  - **`frame.f_locals`**
- Global variables
  - **`frame.f_globals`**
- **`locals() & globals()`**

@lisa_shashkova

Code Object

- **`frame.f_code`** – frame's attribute

Code Object

- Represents a chunk of executable code

Code Object

- Represents a chunk of executable code

```
>>> c = compile('a + b', 'a.py',
'eval')

<code object <module> at
0x104f8fc90, file "a.py", line 1>
```


@lisa_shashkova

Code Object

- Represents a chunk of executable code

```
>>> c = compile('a + b', 'a.py',
'eval')

<code object <module> at
0x104f8fc90, file "a.py", line 1>

>>> eval(c, {'a': 1, 'b': 2})

3
```


@lisa_shashkova

Code Object

- **`code.co_filename`** - filename where it was created
- **`code.co_name`** - name of function or module
- **`code.co_varnames`** - names of variables

Code Object

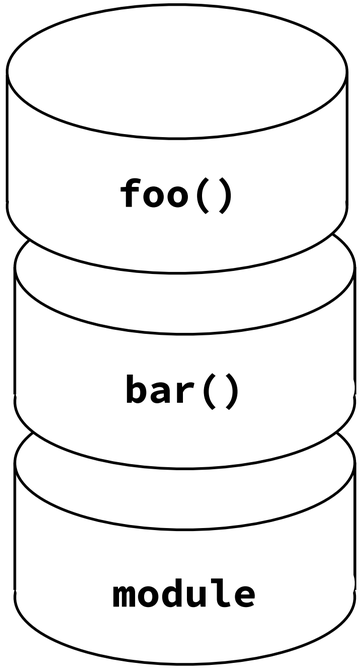
- **`code.co_filename`** - filename where it was created
- **`code.co_name`** - name of function or module
- **`code.co_varnames`** - names of variables
- **`code.co_code`** - compiled bytecode,

  disassemble with **`dis.dis()`**

Frame Object

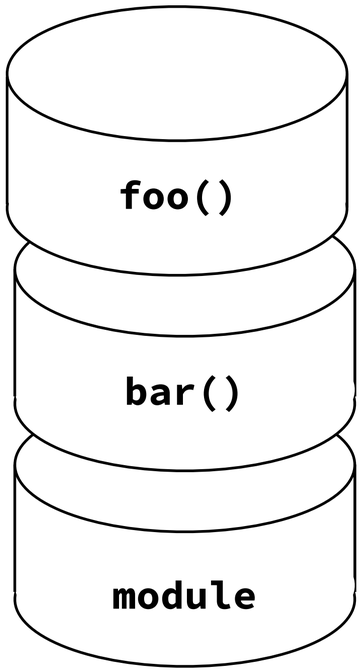
- **`frame.f_lineno`** - current line number
- **`frame.f_trace`** - tracing function
- **`frame.f_back`** - previous frame

Previous Frame



Previous Frame

```
Traceback (most recent call last):
  File "file.py", line 12, in <module>
    print(bar(1))
  File "file.py", line 8, in bar
    res = foo(k)
  File "file.py", line 2, in foo
    raise ValueError("Wrong value!")
ValueError: Wrong value!
```



Frame Object

- **`inspect`** module

Frame Object

- **`inspect`** module
- Handle frame variable carefully!

```
def handle_stackframe_without_leak():
    frame = inspect.currentframe()
    try:
        # do something with the frame
    finally:
        del frame
```


@lisa_shashkova

Contents

- Python Runtime
- Getting Runtime Information
- Development Tools

Contents

- Python Runtime
- Getting Runtime Information
- Development Tools

Development Tools

- AssertionError in **`pytest`**

Exception Object

- **`tb = e.__traceback__`** - traceback object
- **`tb.tb_frame`** - frame object

AssertionError Variables

```
def vars_in_assert(e):
    tb = e.__traceback__
    frame = tb.tb_frame
    code = frame.f_code
    line = tb.tb_lineno - code.co_firstlineno + 1
    source = inspect.getsource(code)
```


@lisa_shashkova

AssertionError Variables

```
def get_vars_names(source, line):
    # get variables names with `ast` module


def vars_in_assert(e):
    tb = e.__traceback__
    frame = tb.tb_frame
    code = frame.f_code
    line = tb.tb_lineno - code.co_firstlineno + 1
    source = inspect.getsource(code)
    for name in get_vars_names(source, line):
        pass
```


@lisa_shashkova

AssertionError Variables

```
def get_vars_names(source, line):
    # get variables names with `ast` module


def vars_in_assert(e):
    tb = e.__traceback__
    frame = tb.tb_frame
    code = frame.f_code
    line = tb.tb_lineno - code.co_firstlineno + 1
    source = inspect.getsource(code)
    for name in get_vars_names(source, line):
        if name in frame.f_locals:
            var = frame.f_locals[name]
            print(f"{name} = {var}")
```


@lisa_shashkova

Usage

```
>>> try:
        assert a + b < 1
    except AssertionError as e:
        vars_in_assert(e)
```

Usage

```
>>> try:
        assert a + b < 1
    except AssertionError as e:
        vars_in_assert(e)


File “/file.py", line 10, in foo
    assert a + b < 1

Variables Values:
a = 1
b = 2
```

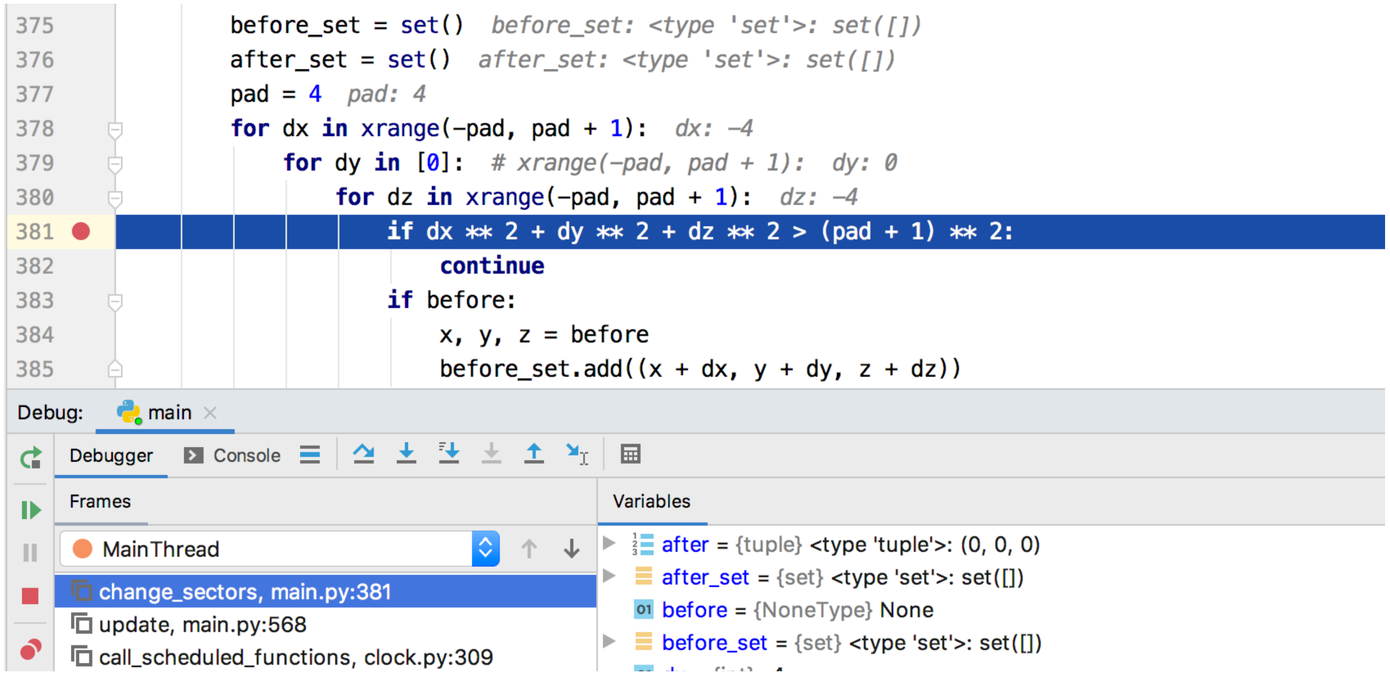
Development Tools

- AssertionError in **`pytest`**

Development Tools

- AssertionError in **`pytest`**
- Debugger

Debugger


375 before_set = set() before_set: <type 'set'>: set([])
376 after_set = set() after_set: <type 'set'>: set([])
377 pad = 4 pad: 4
378 for dx in xrange(-pad, pad + 1): dx: -4
379 for dy in [0]: # xrange(-pad, pad + 1): dy: 0
380 for dz in xrange(-pad, pad + 1): dz: -4
381 if dx ** 2 + dy ** 2 + dz ** 2 > (pad + 1) ** 2:
382 continue
383 if before:
384 x, y, z = before
385 before_set.add((x + dx, y + dy, z + dz))
Debug: main
Debugger
Console
Frames
Variables
MainThread
change_sectors, main.py:381
update, main.py:568
call_scheduled_functions, clock.py:309
after = {tuple} <type 'tuple'>: (0, 0, 0)
after_set = {set} <type 'set'>: set([])
before = {NoneType} None
before_set = {set} <type 'set'>: set([])

Python Debugger

- Tracing function
- Frame evaluation function

Tracing Function

- **`tracefunc(frame, event, arg)`**
- **`sys.settrace(tracefunc)`** - set to current frame
- Stored in a frame: **`frame.f_trace`**
- Debugger analyses events

Frame Evaluation

- **`frame_eval(frame, exc)`**
- Debugger inserts breakpoint's code into code object

More About Debuggers

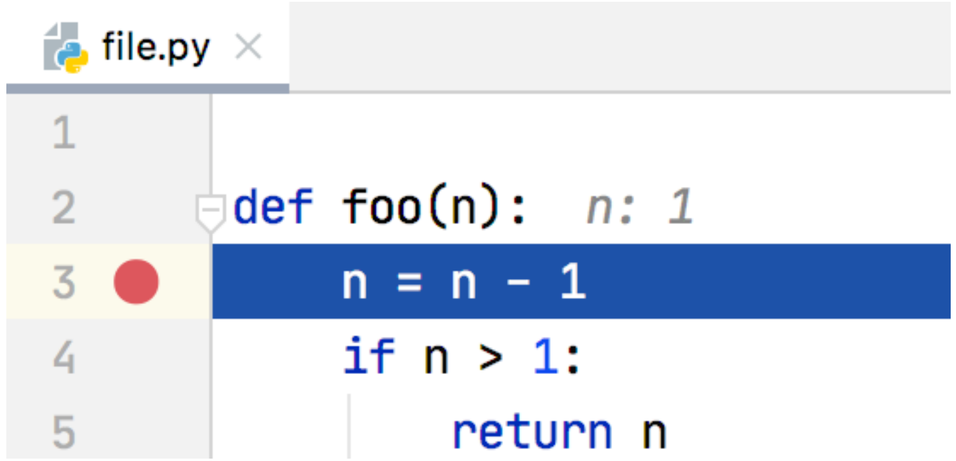
- PyCon US 2017
- “Debugging with Python 3.6: Better, Faster, Stronger”

Access to Frame

- `tracefunc(frame, event, arg)`
- `frame_eval(frame, exc)`

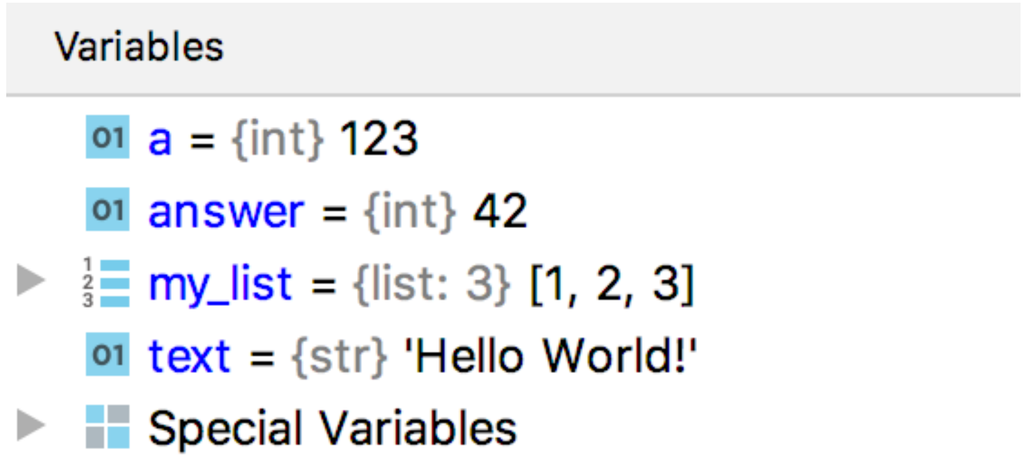
Debugger: Location

- **`frame.f_code.co_filename`** and **`frame.f_lineno`**



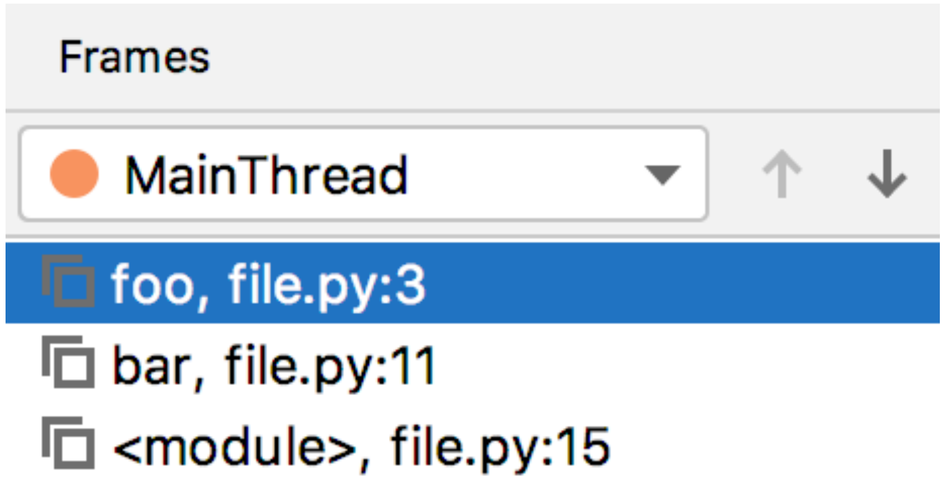
Debugger: Variables

- `frame.f_locals`



Debugger: Frames

- `frame.f_back`



Development Tools

- AssertionError in **`pytest`**
- Debugger

Development Tools

- AssertionError in **`pytest`**
- Debugger
- Code coverage

Code Coverage

- Shows which lines were executed

```
1
2       def foo(n):
3           n = n - 1
4           if n > 1:
5               print(n)
6               return n
7           else:
8               return n + 1
```

coverage.py

- The most popular code coverage library

coverage.py

- `tracefunc(frame, event, arg)`
- `frame.f_code.co_filename` and `frame.f_lineno`

```
1
2       def foo(n):
3           n = n - 1
4           if n > 1:
5               print(n)
6               return n
7           else:
8               return n + 1
```

Development Tools

- AssertionError in **`pytest`**
- Debugger
- Code coverage

Development Tools

- AssertionError in **`pytest`**
- Debugger
- Code coverage
- Runtime typing tools

Typing Tools

- PyAnnotate by Dropbox
- MonkeyType by Instagram
- “Collect Runtime information” in PyCharm

Typing Tools

- PyAnnotate by Dropbox
- MonkeyType by Instagram
- “Collect Runtime information” in PyCharm

Typing Tools

- PyAnnotate by Dropbox
- MonkeyType by Instagram
- “Collect Runtime information” in PyCharm

Typing Tools

- PyAnnotate by Dropbox
- MonkeyType by Instagram
- “Collect Runtime information” in PyCharm

Typing Tools

- PyAnnotate by Dropbox
- MonkeyType by Instagram
- “Collect Runtime information” in PyCharm

Acces To Frame

- PyAnnotate, MonkeyType:
  - `sys.setprofile(profilefunc)`
- `profilefunc(frame, event, arg)`

Acces To Frame

- “Collect Runtime information” in PyCharm
  - Integrated with Debugger
  - Access to a frame object

Collecting Types

```
def arg_names(co):
    nargs = co.co_argcount
    names = co.co_varnames
    return list(names[:nargs])


names = arg_names(frame.f_code)
```

Collecting Types

```
def arg_names(co):
    nargs = co.co_argcount
    names = co.co_varnames
    return list(names[:nargs])


names = arg_names(frame.f_code)
locs = frame.f_locals
objects = [locs[n] for n in names]
```

Typing Tools

- PyAnnotate by Dropbox
- MonkeyType by Instagram
- “Collect Runtime information” in PyCharm

Development Tools

- AssertionError in **`pytest`**
- Debugger
- Code coverage
- Runtime typing tools
- ?

Concurrent Execution

- Threads
- Async Tasks

Python Threads

```
import threading

def fun():
    print("Hello!")


t = threading.Thread(target=fun)
t.start()
t.join()
```


@lisa_shashkova

Synchronisation

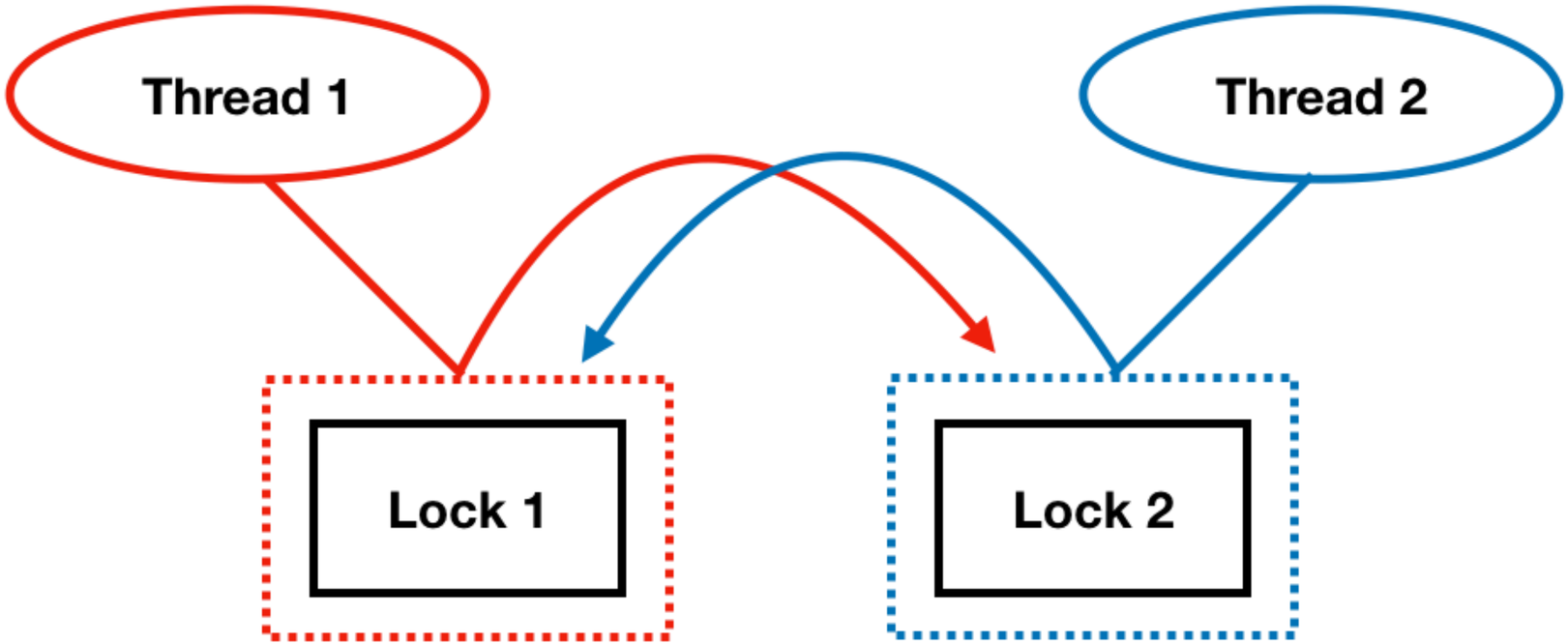
- Lock - fundamental synchronisation object

```
lock = threading.Lock()

lock.acquire()
# only one thread here
lock.release()


with lock:
    # equivalent
```


@lisa_shashkova

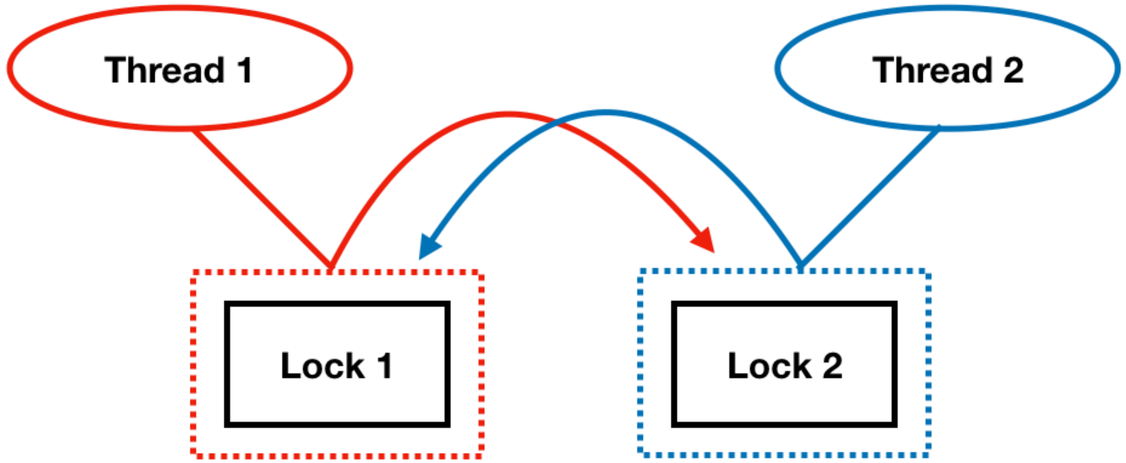
Deadlock

- Waiting for resources which can’t be released



Deadlock

```
def run1():
    with lock1:
        with lock2:
            # do sth

def run2():
    with lock2:
        with lock1:
            # do sth else

Thread(target=run1).start()
Thread(target=run2).start()
```



Deadlock

- Waiting for resources which can’t be released
- Hard to detect in big projects

Thread States

- **`sys._getframe()`** – frame object for current thread
- **`sys._current_frames()`** – topmost stack frame for each thread

Thread Handler

- Print tracebacks for threads with interval
- Help to find deadlock location

Fault Handler

- **`faulthandler.dump_traceback(file)`**
- Dumps the tracebacks of all threads info file
- Implemented natively

Concurrent Execution

- Threads
- Async Tasks

Async Locks

```
alock = asyncio.Lock()

alock.acquire()
# only one task here
alock.release()


async with alock:
    # equivalent
```


@lisa_shashkova

Async Fault Handler

- **`asyncio.all_tasks(loop)`** - all the running tasks
- **`Task.get_stack()`** - list of stack frames for this Task

Async Fault Handler

- In a separate thread:

```
def dump_traceback_later(timeout, loop):
    while True:
        sleep(timeout)
        dump_traceback(loop, timeout)
```

Async Fault Handler

- In a separate thread:

```
def dump_traceback(loop):
    for task in asyncio.all_tasks(loop):
        task.print_stack()


def dump_traceback_later(timeout, loop):
    while True:
        sleep(timeout)
        dump_traceback(loop, timeout)
```

Development Tools

- AssertionError in **`pytest`**
- Debugger
- Code coverage
- Runtime typing tools
- (Async) Fault Handler

The Hidden Power of Runtime

- Python Runtime is very powerful
- Easy access to stack frame and code objects
- Development Tools:
    - pytest, Debugger, Code Coverage, Typing Information, Fault Handler

Inspiration

- Use existing Runtime Development Tools (more often)
- Create something new!

Links

- https://github.com/Elizaveta239/PyRuntimeTricks
- https://elizaveta239.github.io/the-hidden-power-part1/
- elizaveta.shashkova@jetbrains.com
- Discord: #talk-python-runtime