Statistical Profiling

(and other neat features of the `sys` module)

Outline

1. Why statistical profiling?
2. Various python tools available.
3. Details of `ox_profile` statistical profiler.

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Goal:

- learn how to use `ox_profile`, other profilers

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2. Various python tools available.
3. Details of `ox_profile` statistical profiler.

Goal:

- learn how to use `ox_profile`, other profilers
- or write your own!

What is profiling?

From python.org:

- "A profile is a set of statistics that describes how often and for how long various parts of the program executed."

Profiling is useful to find out which parts of program are slow.

Deterministic Profiling

```
>>> import cProfile, re  # could also use pure python `profile`
>>> cProfile.run('re.compile("foo|bar")')
```

gives:

```
      197 function calls (192 primitive calls) in 0.002 seconds

Ordered by: standard name

ncalls  tottime  percall  cumtime  percall filename:lineno(function)
     1    0.000    0.000    0.001    0.001 <string>:1(<module>)
     1    0.000    0.000    0.001    0.001 re.py:212(compile)
     1    0.000    0.000    0.001    0.001 re.py:268(_compile)
     1    0.000    0.000    0.000    0.000 sre_compile.py:172(_compile_charset)
     1    0.000    0.000    0.000    0.000 sre_compile.py:201(_optimize_charset)
     4    0.000    0.000    0.000    0.000 sre_compile.py:25(_identityfunction)
   3/1    0.000    0.000    0.000    0.000 sre_compile.py:33(_compile)
```

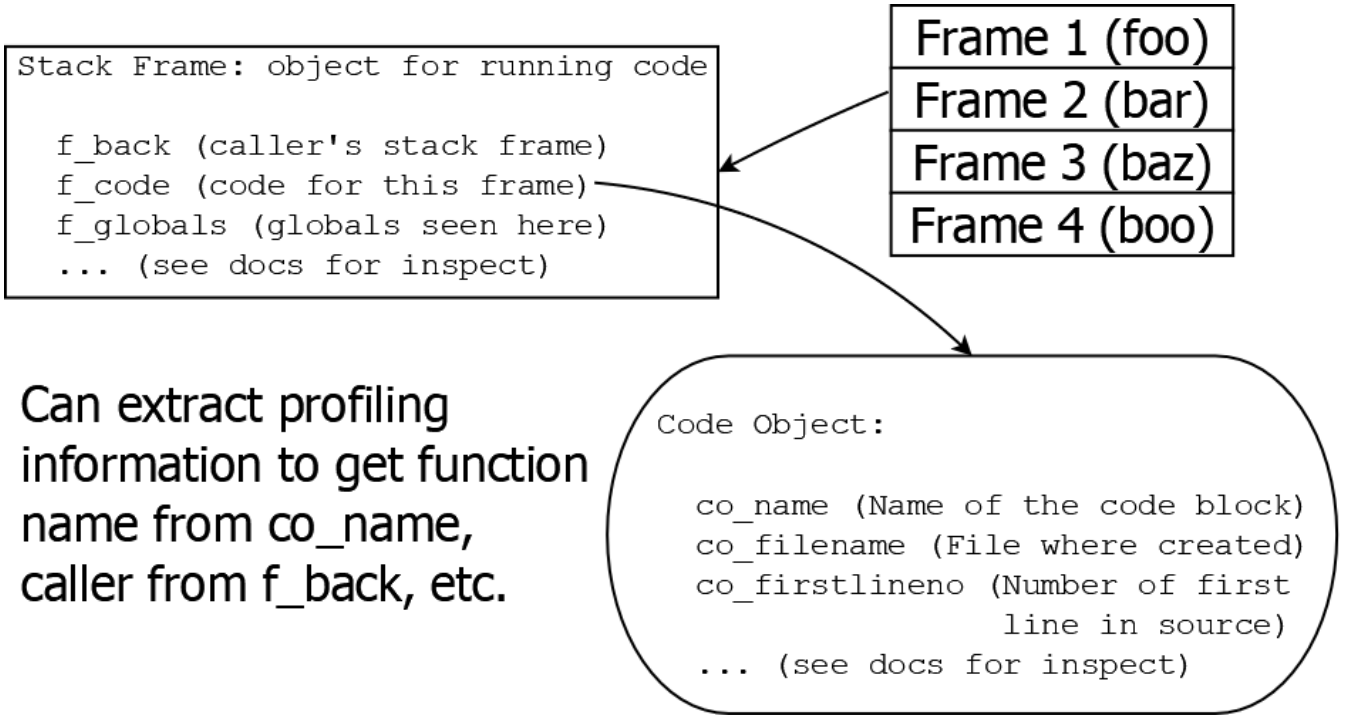
Deterministic profiling hooks

The `sys` module provides:

- `setprofile`: execute function on each call.
- `settrace`: like `setprofile` + each line

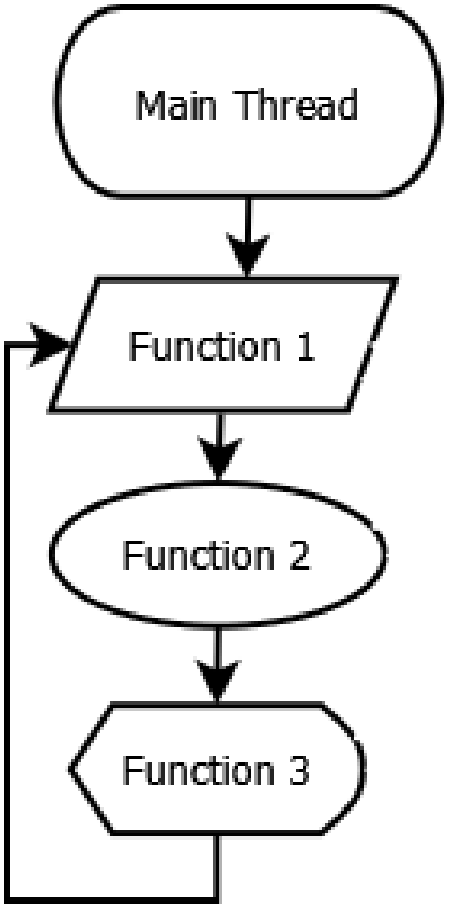
Used as a hook to inspect stack frame.

Python Stack Frame

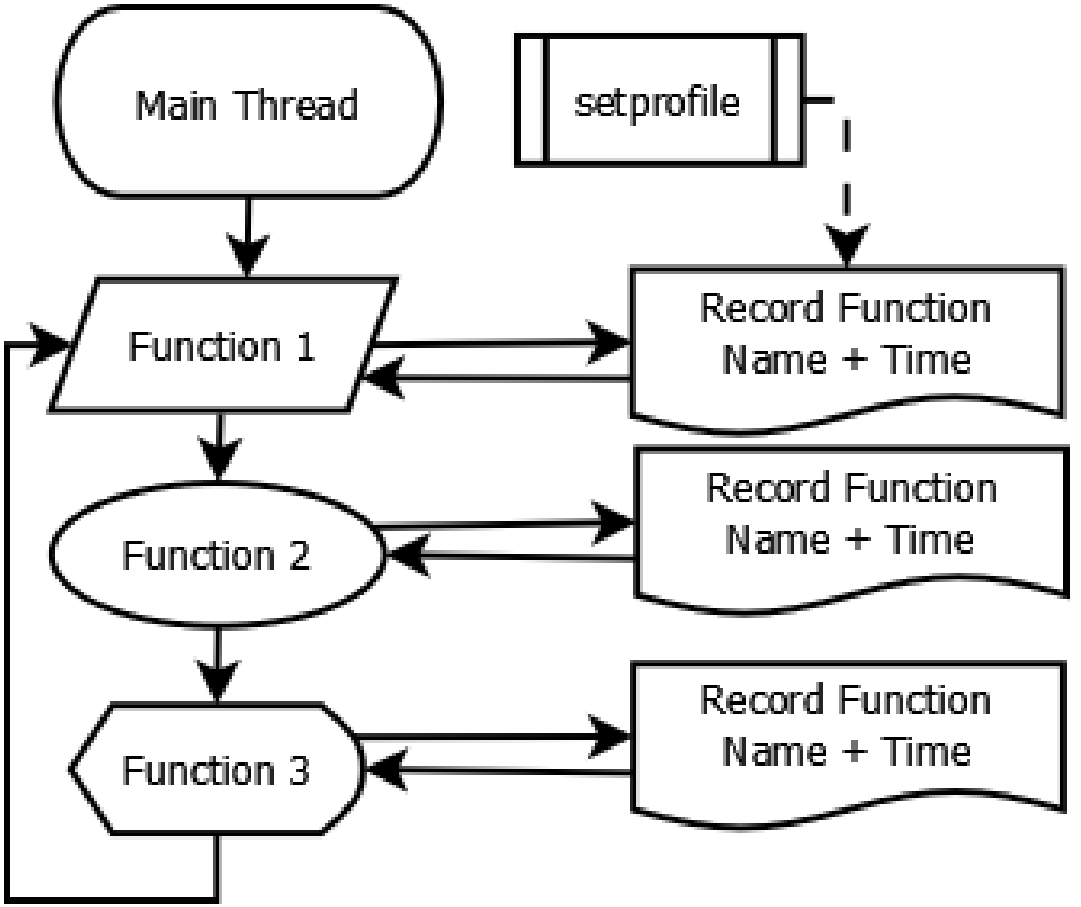


Can extract profiling information to get function name from co_name, caller from f_back, etc.

Program Diagram



Program Diagram w/Profiler



Drawbacks to deterministic profiling

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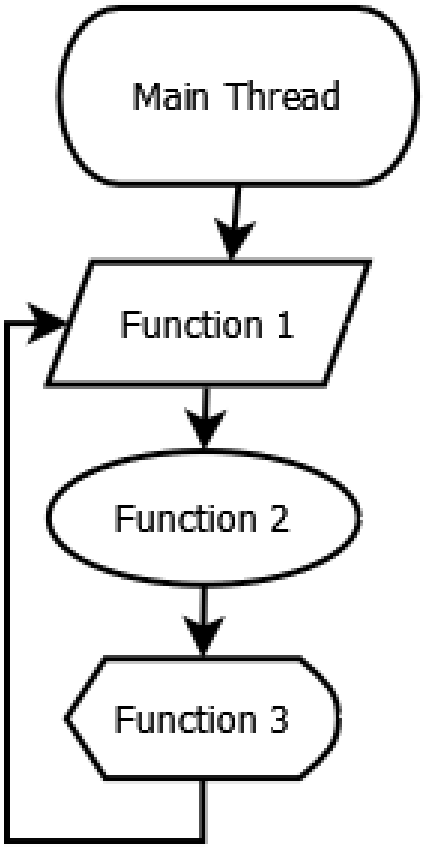
2. See #1: usually can't profile in production.
3. Not thread-aware:

> "it must be registered using `settrace()` for each thread being debugged" (similar for `setprofile()`).

Statistical Profiler (Main Thread)

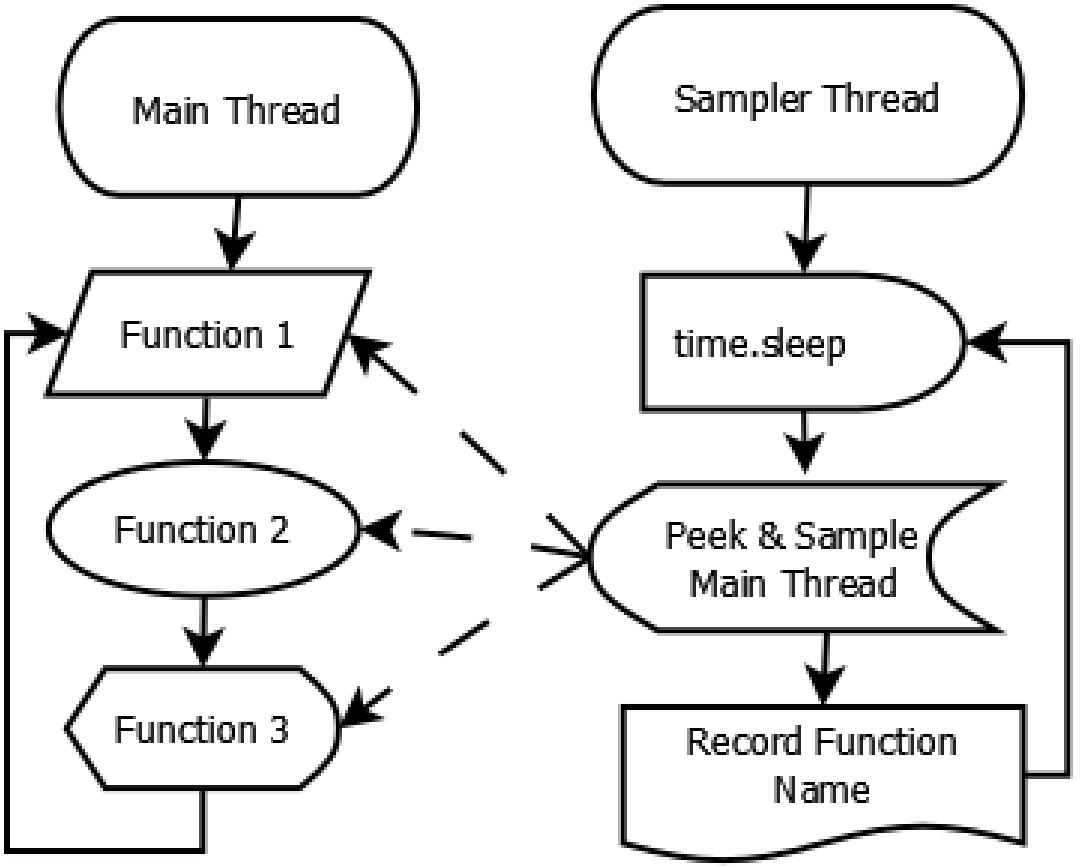


Stastical Profiler periodically checks program state.

Records a "sample" of what function program is running.

Only runs "occasionally" so overhead is low.

Statistical Profiler (Sampling)



POSIX timer as Sampler

- Low level timer interrupts your process
- Periodically check call stack + record it.
- `stat_prof`, `plop` (not available on Windows).

POSIX ptrace as Sampler

- Threads via `ptrace`.
- Lets one program control/inspect other.
- Main/Sampler are different programs!
- `pyflame` (not available on Windows).

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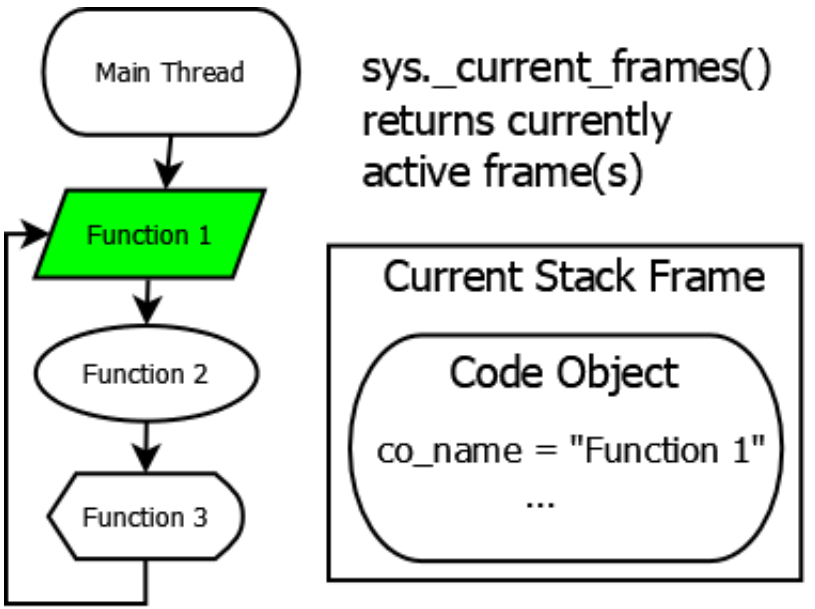
1. Nice to have "portable" implementation.
2. Using only python features may be easier to understand/modify.
    - Understandable implementation essential if run in production.
3. Consumer software (e.g., games) often run in Windows.

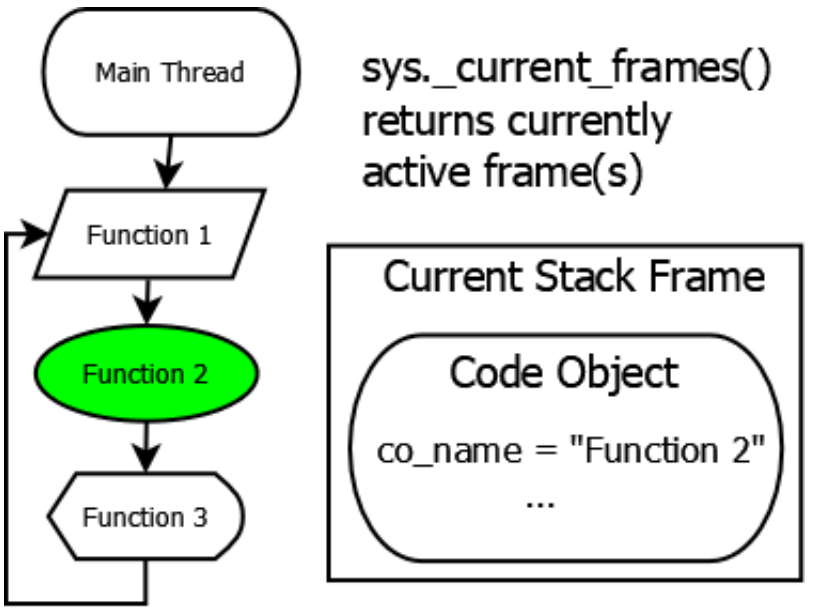
Python `sys._current_frames`

- lists each thread's current frame.
- `ox_profile`, `pprofile`, (works on windows!)



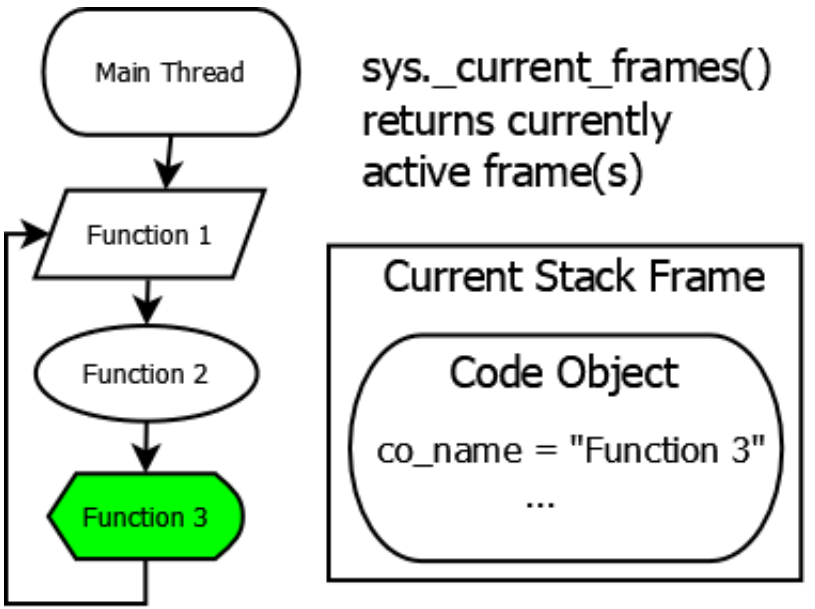
`_current_frames` (Function 2)

- lists each thread's current frame.
- `ox_profile`, `pprofile`, (works on windows!)



`_current_frames` (Function 3)

- lists each thread's current frame.
- `ox_profile`, `pprofile`, (works on windows!)



Logistics: How do we profile?

Install via the usual

```
$ pip install ox_profile
```

Then start your python interpreter and:

```
>>> from ox_profile.core.launchers import SimpleLauncher
>>> profiler = SimpleLauncher.launch() # Create + start
>>> # call some functions
>>> print(profiler.show())             # Show results
>>> profiler.cancel()                  # Turn off
```

Sampling loop

Oversimplified illustration of sampler loop:

```
    while 1:
        time.sleep(self.interval)
        for id, frame in sys._current_frames().items():
            self.my_db[frame.f_code.co_name] += 1
```

Sampling loop runs in separate thread.

Sampling Interval

Control overhead based on sampling interval:

```
>>> profiler.set_interval(5)  # changes profiler.interval
```

- 5 second sampling = negligable overhead.
- Trade-off between various goals:
  - accuracy, collection time, overhead
- May want to also add random jitter

Profiler output

```
>>> profiler.show()
```

Output shows:

- Function name (and module).
- How many times function was seen.

```
 Function                                          Hits    %
-------------------------------------------------------------
 send(requests.sessions)                          10082    2.8
 request(requests.api)                             7710    2.1
 get(requests.api)                                 7710    2.1
<listcomp>(__main__)                               7710    2.1
__call__(ox_profile.core.sampling)                 7710    2.1
request(requests.sessions)                         7698    2.1
send(requests.adapters)                            6897    1.9
_make_request(urllib3.connectionpool)              6893    1.9
urlopen(urllib3.connectionpool)                    6893    1.9
connect(urllib3.connection)                        5602    1.5
```

Basic theory of sys._current_frames

1. Start thread doing mostly `time.sleep`.
2. Periodically wake + `sys._current_frames()`
3. Record current stack frame(s) info.

In theory, you can write simple statistical profiler with just these.

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In theory, there is no difference between theory and practice.

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In theory, there is no difference between theory and practice.

- But, in practice, there is.

Using sys._current_frames

In theory, just step through `sys._current_frames()` and record data.

```
        for dummy_frame_id, frame in (sys._current_frames().items()):
            self.my_db.record(measure_tool(frame))
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What could go wrong?

- thread context could switch
  - attempt to read stale frame = **CRASH!**

Using sys._current_frames

In theory, just step through `sys._current_frames()` and record data.

```
        switch_interval = sys.getswitchinterval()
        sys.setswitchinterval(10000)

        for dummy_frame_id, frame in (sys._current_frames().items()):
            self.my_db.record(measure_tool(frame))

        sys.setswitchinterval(switch_interval)
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`sys.setswitchinterval` prevents context switch.

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`sys.setswitchinterval` prevents context switch.

Now, what could go wrong?

- Exception prevents switch interval being reset!

Using sys._current_frames

In theory, just step through `sys._current_frames()` and record data.

```
        switch_interval = sys.getswitchinterval()
        try:
            sys.setswitchinterval(10000)
            for dummy_frame_id, frame in (
                    sys._current_frames().items()):
                self.my_db.record(measure_tool(frame))
        finally:
            sys.setswitchinterval(switch_interval)
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`sys.setswitchinterval` prevents context switch.

Need `try/finally` to protect thread logic.

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`sys.setswitchinterval` prevents context switch.

Need `try/finally` to protect thread logic.

Now, what could go wrong?

- We are just getting started.

Recording a sample

Simple function to record a sample in `dict`:

```
    def record(self, measurement):
        record = self.my_db.get(measurement.name, 0)
        self.my_db[measurement.name] = record + 1
```

- keep dict of measurements
- find + increment hit for given function

What could go wrong?

Recording sample changing dict

- Imagine getting profile results

```
    def record(self, measurement):
        record = self.my_db.get(measurement.name, 0)
        self.my_db[measurement.name] = record + 1
```

- If `record` being called
  - change dict during iteration = **CRASH**!

Recording a sample

```
    def __init__(self):
        self.db_lock = threading.Lock()

    def record(self, measurement):
        with self.db_lock:
            record = self.my_db.get(measurement.name, 0)
            self.my_db[measurement.name] = record + 1
```

- Need to use `threading.Lock`
  - Must check lock in viewing `self.my_db`
- Prevents simultaneous access to `my_db`

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- Need to use `threading.Lock`
  - Must check lock in viewing `self.my_db`
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What could go wrong?

- Unknown unknowns:
  - use `faulthandler.enable()` at startup

Additional Issues

- Sampler thread still alive on exit program
  - Set `self.daemon = True` for sampler
- Minimum sleep time ~ 1--10 milliseconds
  - For time.sleep or wait on a thread event.
  - Granularity about 10 milliseconds.

Using Flask

If you are running a flask web server, do:

```
from ox_profile.ui.flask.views import OX_PROF_BP
app.register_blueprint(OX_PROF_BP)
app.config['OX_PROF_USERS'] = {<admin_user_1>, <admin_user_2>, ...}
```

for easy way to profile production code:

- `ox_profile/unpause`: Start (or unpause)
- `ox_profile/pause`: Pause profiler
- `ox_profile/status`: Shows current results
- `ox_profile/set_interval`: sample frequency

Additional Uses

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Be careful!

Idea: Data Snapshot

- Periodically snapshot specific function data
- Instead of `frame.f_code.co_name`,
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- Instead of `frame.f_code.co_name`,
- Just look at `frame.f_locals`
  - Can even modify `f_locals`!

Idea: Statistical Debugger

- Periodically snapshot debug info
  - full stack backtrace + locals
- Either dump these to logs
- or store locally and report on "failure".

Idea: Statistical code coverage

- Like `coverage.py`, but in production
- Periodically turn on tracing
- After brief sample, turn back off

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4. `sys.setprofile`, `sys.settrace`, `sys._current_frames`

Summary

1. Profiling find bottlenecks + improve your code.
2. Statistical profiler samples code periodically
    - use to analyze production with low overhead.
3. Use `ox_profile` or write your own profiler.
4. `sys.setprofile`, `sys.settrace`, `sys._current_frames`
5. Simple in theory; but be careful with threads:
    - `try/finally`, locks, switch interval, `faulthandler`

Further investigations

- Slides, `ox_profile`, etc. at https://github.com/emin63/ox_profile
  - Clone, fork, or file issues for questions.
- About presenter:
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  - Contact: emin.martinian@gmail.com