Python Performance
Investigation by Example

@jiffyclub

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About Me

- Matt Davis aka @jiffyclub
- Data Engineer at Clover Health (visit us at the Job Fair!)
- http://penandpants.com
- Photos/tweets welcome
- github.com/jiffyclub/pycon-2018-talk
-

Caveats about “Performance”

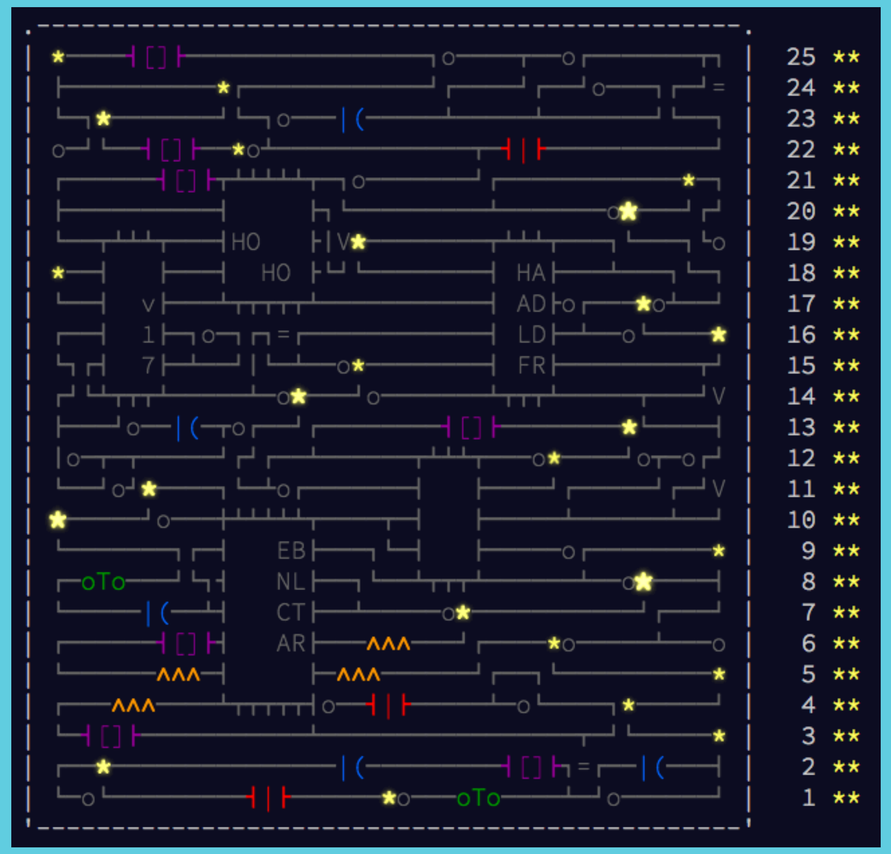
http://www.attorneysforanimals.org/wp-content/uploads/2016/07/animal-law-book-cat.jpg

The Recipe

1. Collect Data
2. Analyze
3. Experiment
4. GOTO 1

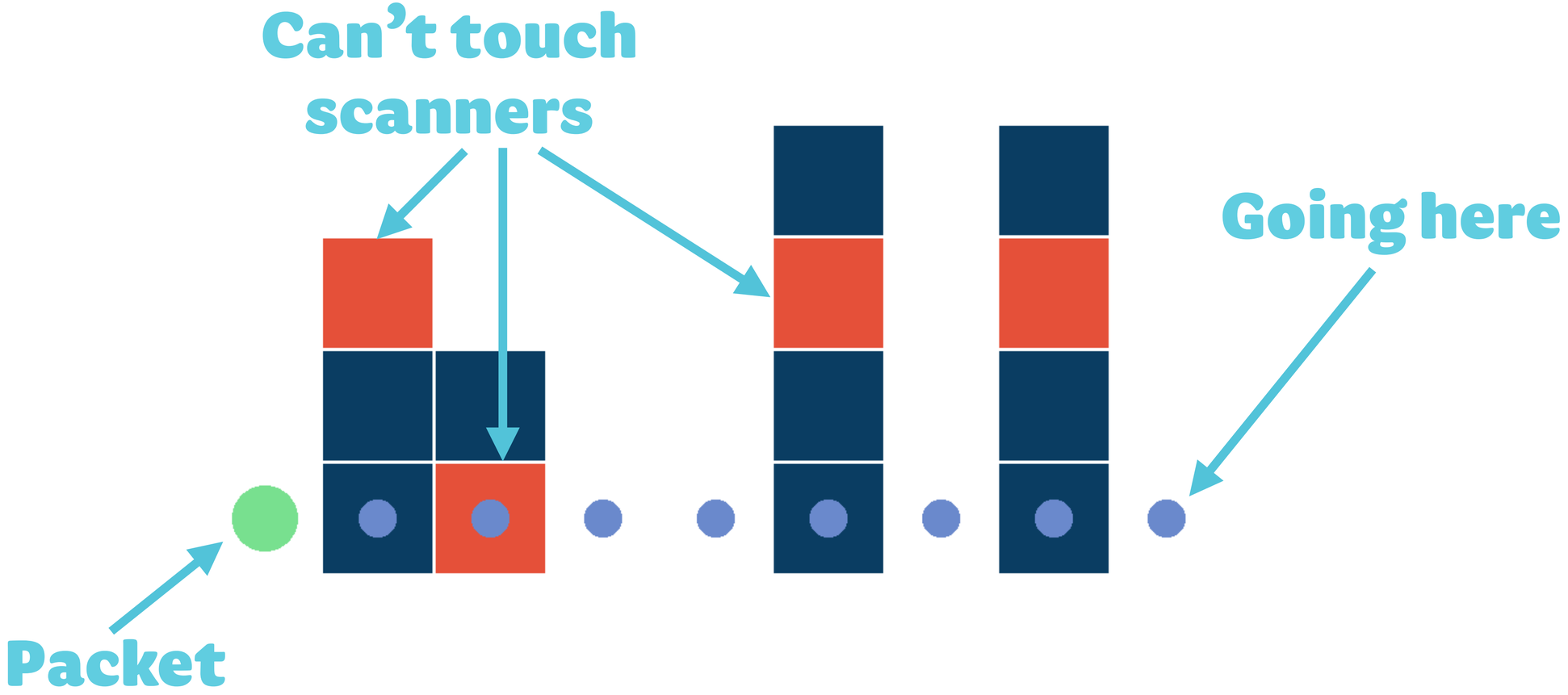
https://www.etsy.com/listing/257563486/science-cat-funny-pinback-button-cute

Backstory

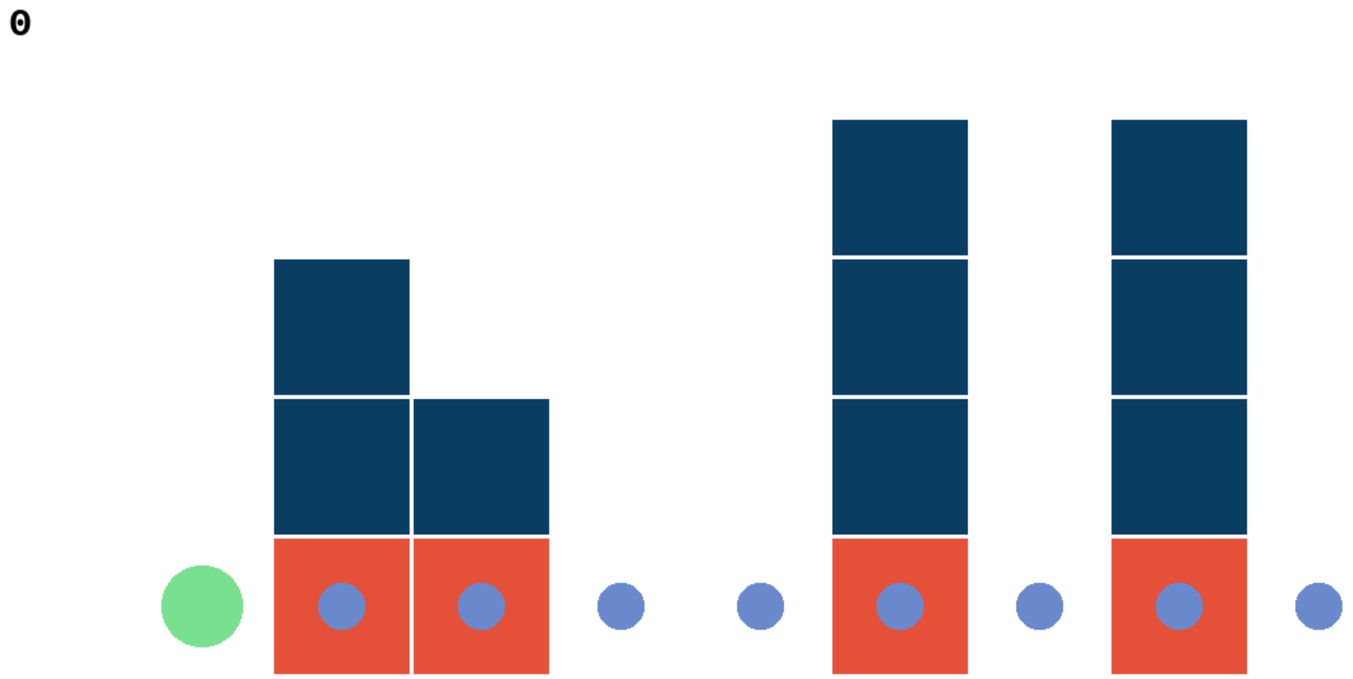


adventofcode.com/2017

The Assignment: Evade a “Firewall”



The Assignment: Evade a “Firewall”



Solution Outline

```
def find_start(firewall) -> int:
    ...
    for t_start in itertools.count(0):
        ...
        if check_capture(firewall, num_layers):
            ...
        else:
            break
    return t_start
```

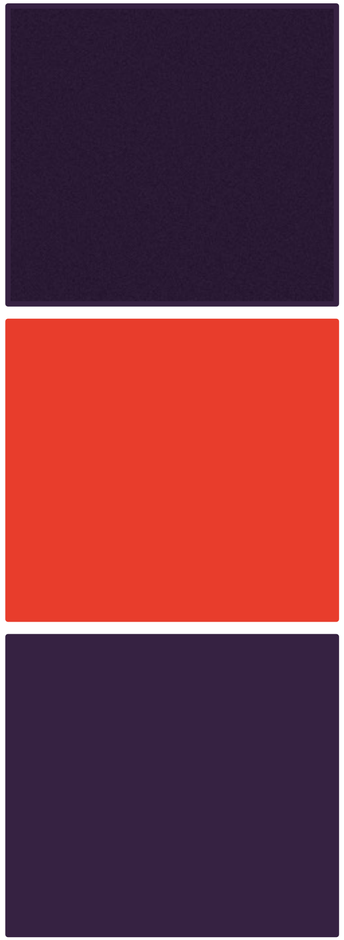
Infinite loop

Did we get caught?

Break out if we didn't get caught

First Try (Scanner)

```
class Scanner:
```



- height
- position
- direction
- advance()
- copy()

First Try (firewall)

```
firewall = {scanner_slot: Scanner()}
```

First Try (check_capture)

```
def check_capture(
        firewall: Dict[int, Scanner], num_layers: int) -> bool:
    for packet_pos in range(num_layers):
        if packet_pos in firewall and firewall[packet_pos].pos == 0:
            return True

        for scanner in firewall.values():
            scanner.advance()

    return False
```

Each position in firewall

First Try (check_capture)

```
def check_capture(
        firewall: Dict[int, Scanner], num_layers: int) -> bool:
    for packet_pos in range(num_layers):
        if packet_pos in firewall and firewall[packet_pos].pos == 0:
            return True
        for scanner in firewall.values():
            scanner.advance()

    return False
```

Is there a scanner?

Is the scanner at the bottom?

First Try (check_capture)

```
def check_capture(
        firewall: Dict[int, Scanner], num_layers: int) -> bool:
    for packet_pos in range(num_layers):
        if packet_pos in firewall and firewall[packet_pos].pos == 0:
            return True

        for scanner in firewall.values():
            scanner.advance()

    return False
```

Advance scanner state one time-step

First Try (find_start)

```
def find_start(firewall: Dict[int, Scanner]) -> int:
    loop_firewall = copy_firewall(firewall)
    num_layers = max(firewall.keys()) + 1
    for t_start in itertools.count(0):
        pre_check_firewall = copy_firewall(loop_firewall)
        if check_capture(loop_firewall, num_layers):
            loop_firewall = copy_firewall(pre_check_firewall)
            for scanner in loop_firewall.values():
                scanner.advance()
        else:
            break
    return t_start
```

Did It Work?

Answer: 3,823,370 time-steps

How Long Did it Take?

Did It Work?

Answer: 3,823,370 time-steps

How Long Did it Take?

10 minutes (600 seconds)

Thoughtful Time

https://hoschie.deviantart.com/art/Thinking-cat-346209983

Collecting Data a.k.a. Profiling

cProfile

Built into Python

Tracks time spent in functions

Others

line_profiler

pyflame

plop

nylas-perftools

Running cProfile

```
python -m cProfile \
       -o output_file \
       my_script.py

%%prun -q -D output_file
```

IPython magic

Viewing Data (pstats)

Loading profile data

```
In [2]: data = pstats.Stats(‘slow_mode.cprof')
In [3]: data.sort_stats('cumulative').print_stats('slow_mode', 2)
```

…

```
   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
        1    0.000    0.000  808.171  808.171 slow_mode.py:1(<module>)
        1   93.039   93.039  808.156  808.156 slow_mode.py:74(find_start)
```

Viewing Data (pstats)

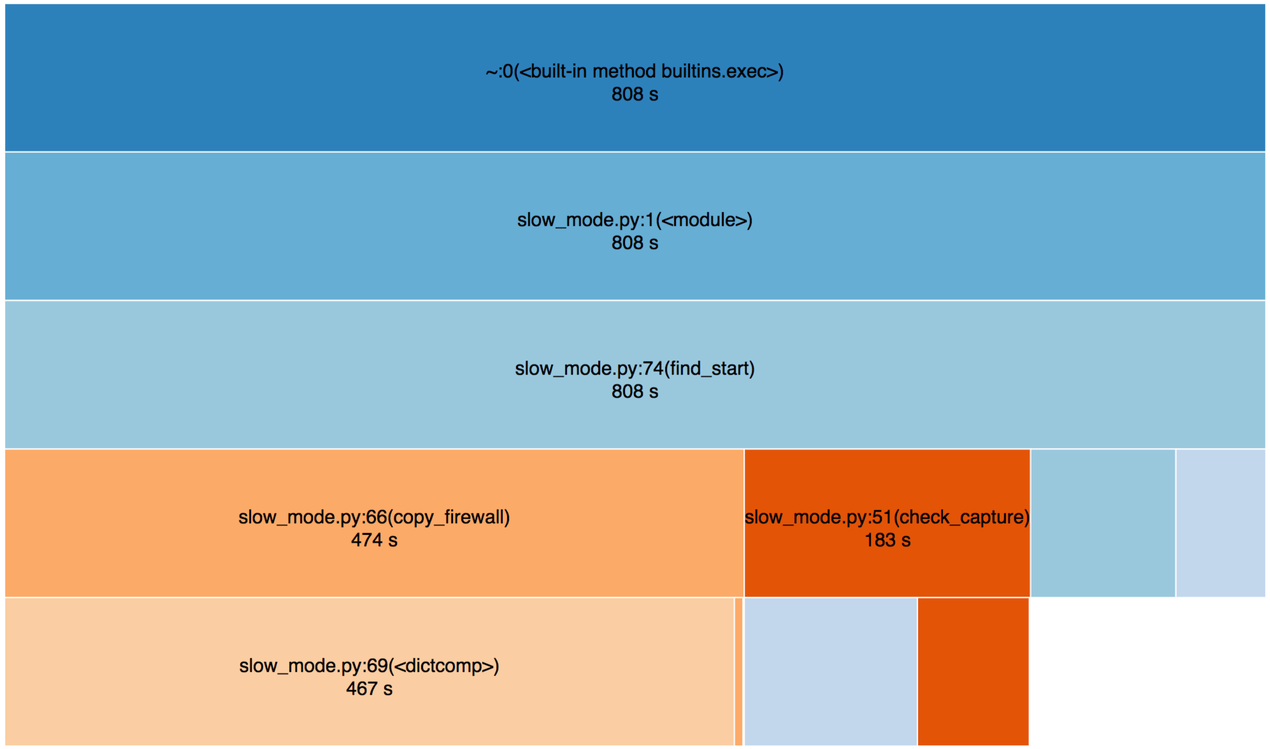
```
In [4]: data.sort_stats('tottime').print_stats(2)
```

…

```
   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
328809906  234.089    0.000  364.089    0.000 slow_mode.py:28(copy)
488635144  168.532    0.000  168.532    0.000 slow_mode.py:13(advance)
```

SnakeViz!

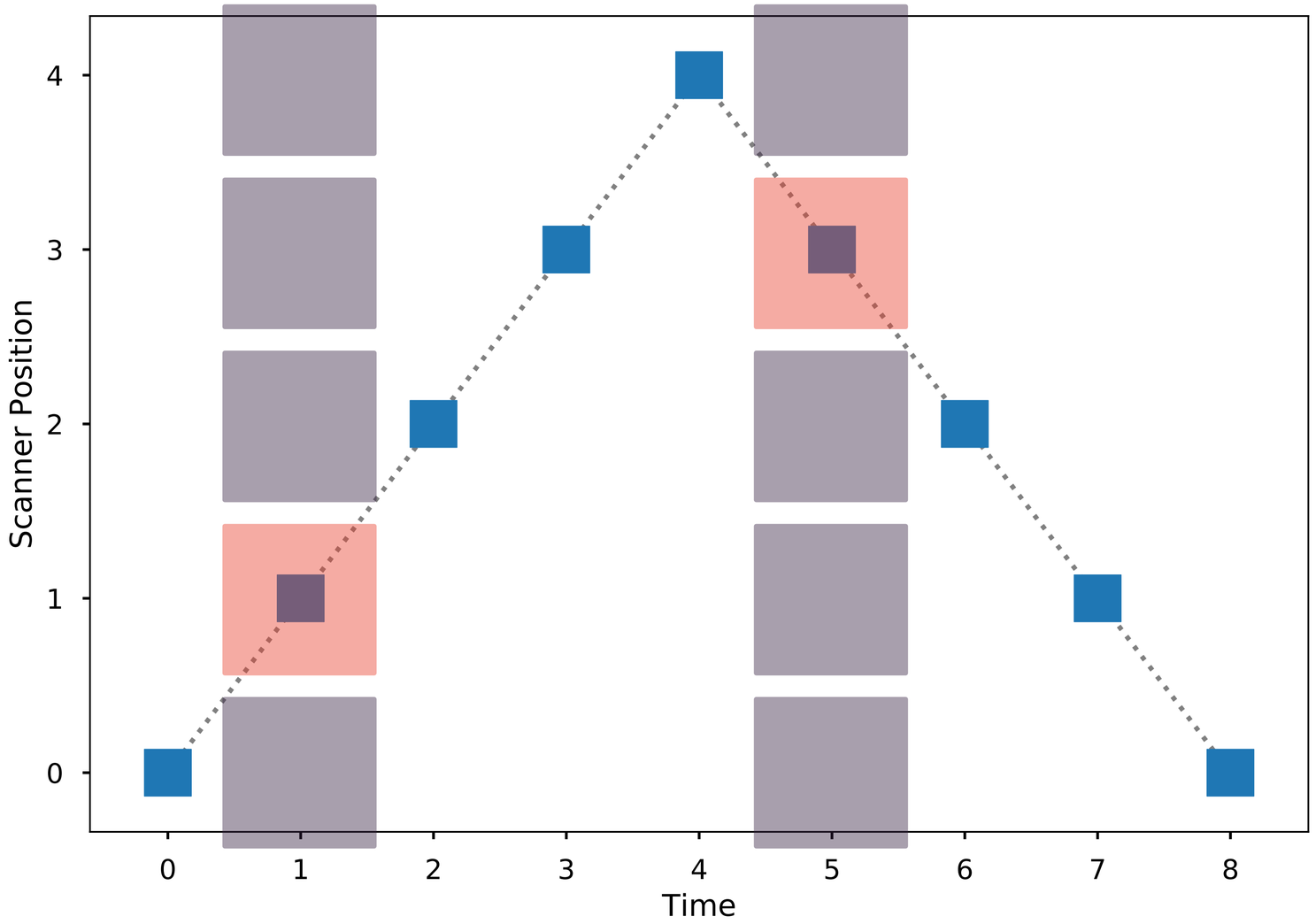
```
pip install snakeviz
snakeviz slow_mode.cprof
```



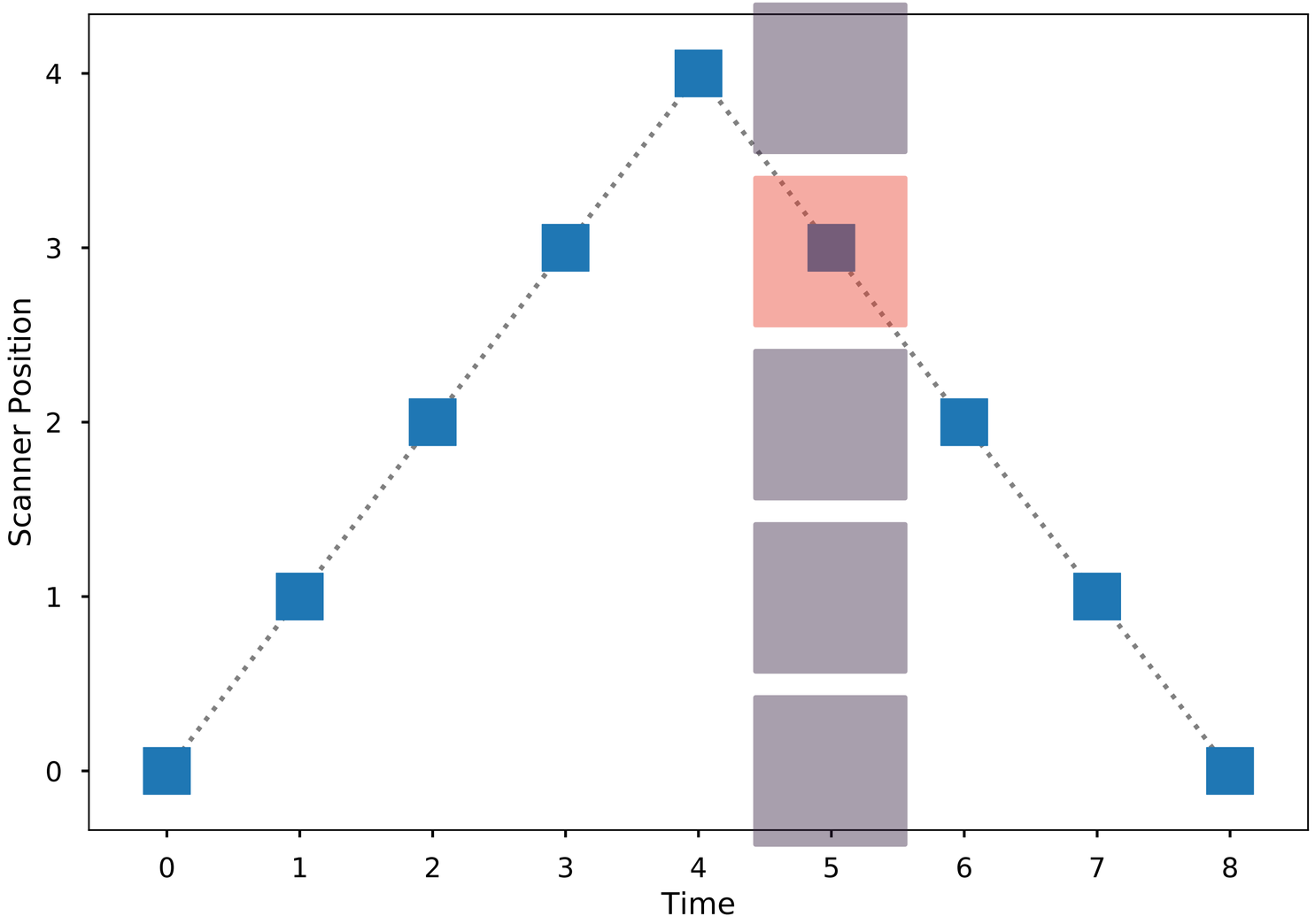
First Try (find_start)

```
def find_start(firewall: Dict[int, Scanner]) -> int:
    loop_firewall = copy_firewall(firewall)
    num_layers = max(firewall.keys()) + 1
    for t_start in itertools.count(0):
        pre_check_firewall = copy_firewall(loop_firewall)
        if check_capture(loop_firewall, num_layers):
            loop_firewall = copy_firewall(pre_check_firewall)
            for scanner in loop_firewall.values():
                scanner.advance()
        else:
            break
    return t_start
```

Math is Magic



Math is Magic



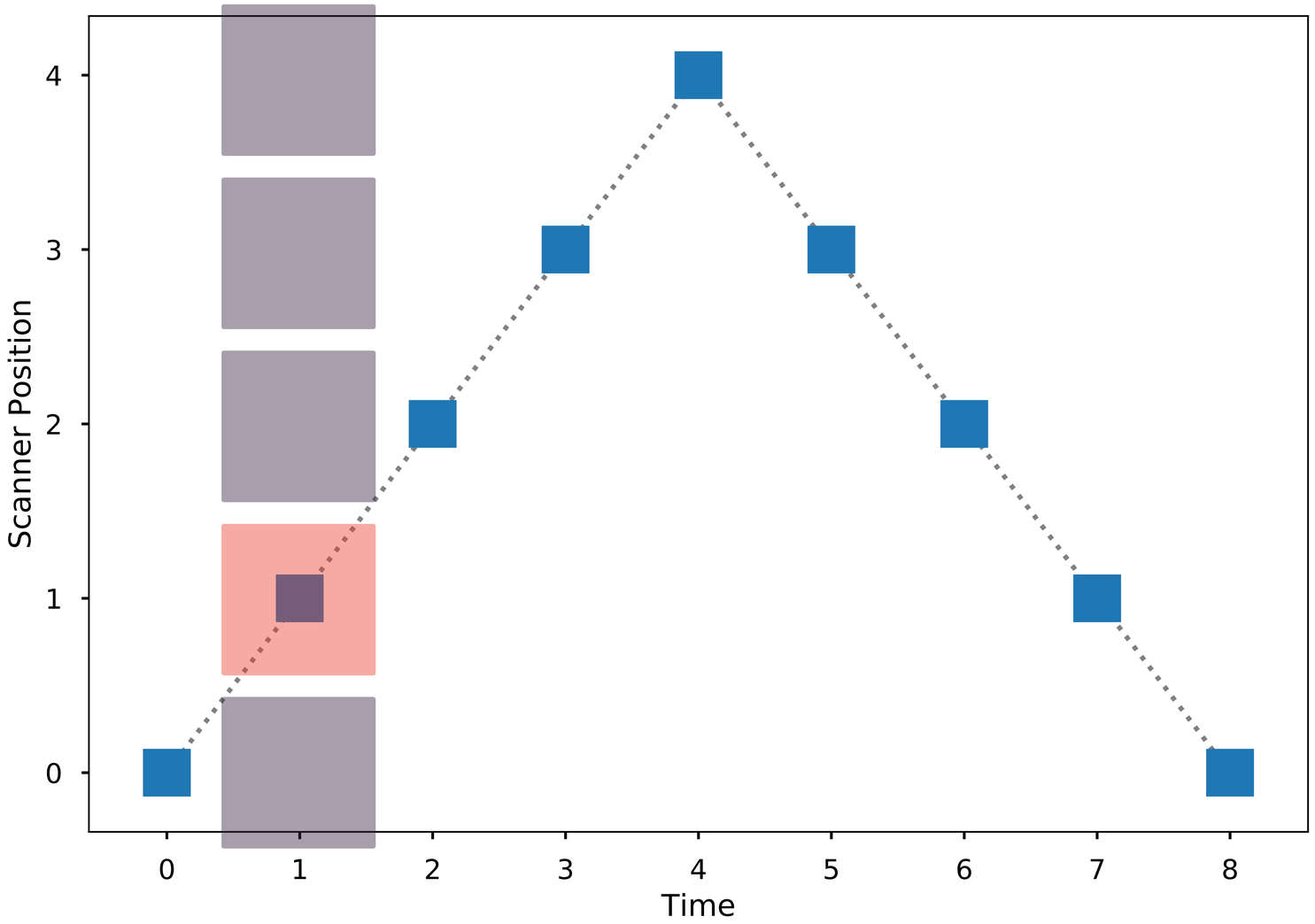

```
scanner_height = 5
cycle_width = 8

time_step = 21

cycle_pos = time_step % 8
  -> 5

return 8 - 5
  -> 3
```

Math is Magic




```
scanner_height = 5
cycle_width = 8

time_step = 65

cycle_pos = time_step % 8
  -> 1

return 1
```

Second Try (scanner_layer)

```
def scanner_layer(
        scanner_height: int, time_step: int) -> int:
    cycle_midpoint = scanner_height - 1
    cycle_width = cycle_midpoint * 2
    cycle_position = time_step % cycle_width
    return (
        cycle_position
        if cycle_position <= cycle_midpoint
        else cycle_width - cycle_position)
```

Second Try (firewall)

```
firewall = {scanner_slot: scanner_height}
```

Second Try (check_capture)

```
def check_capture(firewall: dict, num_layers: int, t_start: int) -> bool:
    for pos in range(num_layers):
        if pos in firewall:
            scanner_height = firewall[pos]
            scanner_pos = scanner_layer(scanner_range, t_start + pos)
            if scanner_pos == 0:
                return True
    return False
```

Is there a scanner?

Is the scanner at the bottom?

Second Try (find_start)

```
def find_start(firewall: dict) -> int:
    num_layers = max(firewall.keys()) + 1
    for t_start in itertools.count(0):
        if not check_capture(firewall, num_layers, t_start):
            break
    return t_start
```

Infinite loop

Did we get caught?

Break out if we didn't get caught

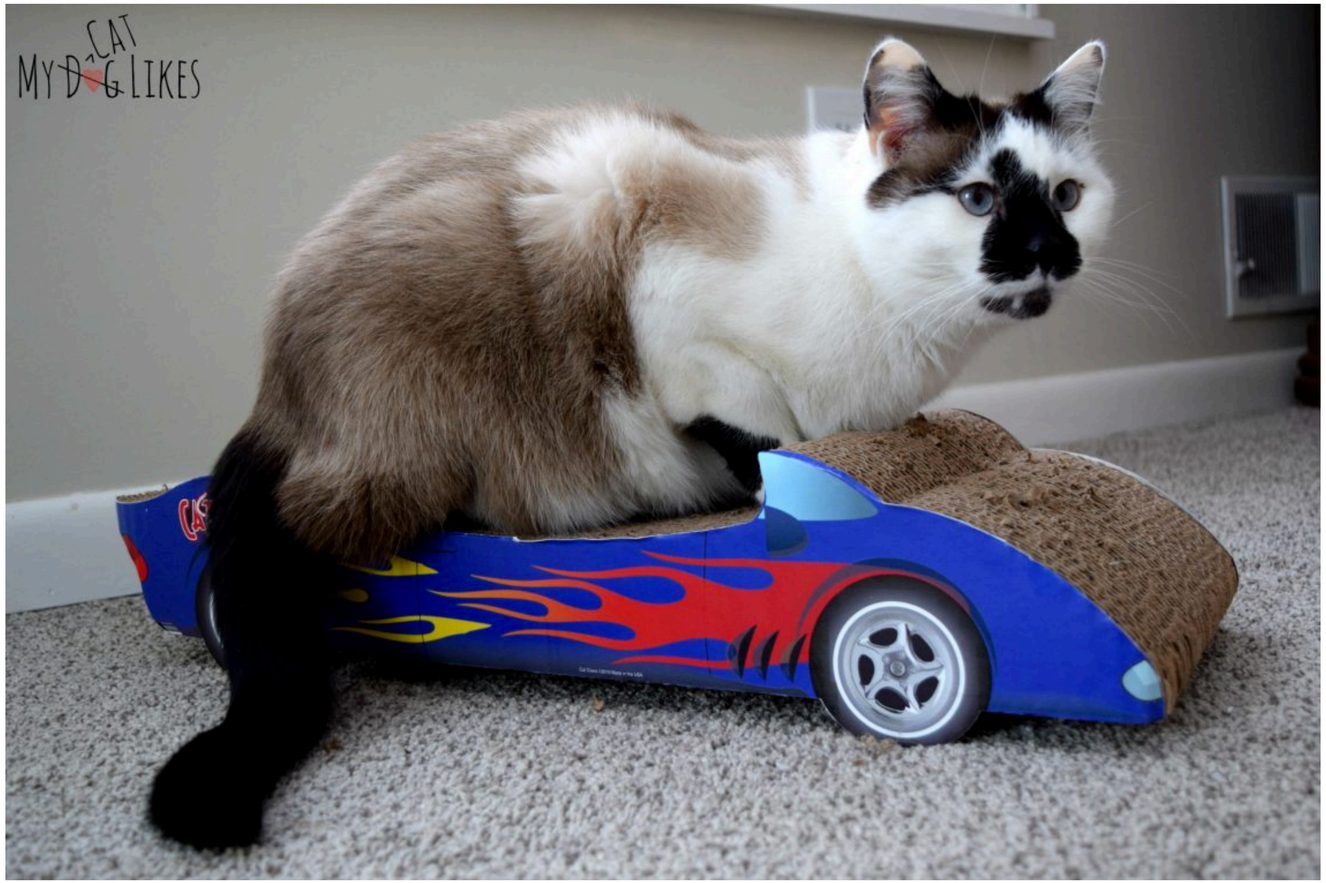
Did It Work?

Answer: 3,823,370 time-steps

How Long Did it Take?

~6 seconds

Cool, cool. Can we go faster?



https://mycatlikes.com/cat-claws-convertible-cat-scratcher-review/

Results

	Time (milliseconds)
First Try	600,000
Second Try	6,000
PyPy	600
Numba	2
Cython	1

Array Firewall

```
firewall = [3, 2, 0, 0, 4, 0, 4]
```

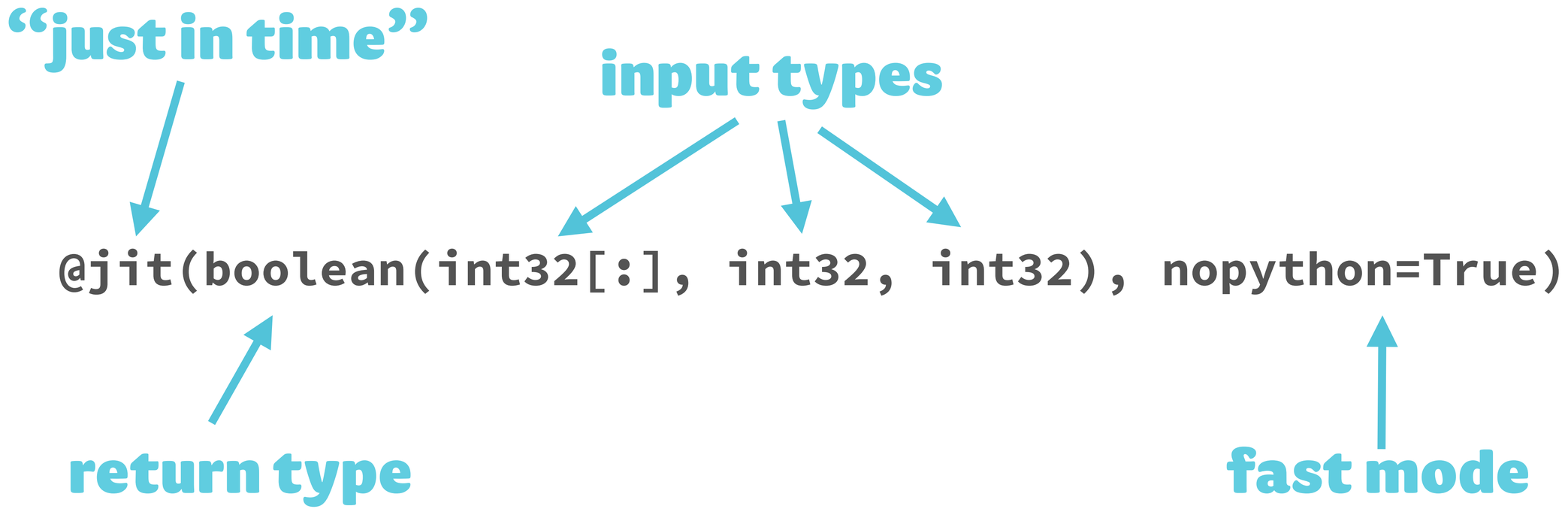
Numba

Compiles Python on-the-fly

100% plain Python

Used with NumPy for maths

Numba @jit


“just in time”
input types
@jit(boolean(int32[:], int32, int32), nopython=True)
return type
fast mode

Numba (check_capture)

Numba decorator

```
@jit(boolean(int32[:], int32, int32), nopython=True)
def check_capture(firewall: np.array, num_layers: int, t_start: int) -> bool:
    for pos in range(num_layers):
        if firewall[pos] != 0:
            scanner_pos = scanner_layer(firewall[pos], t_start + pos)
            if scanner_pos == 0:
                return True
    return False
```

Is there a scanner?

Is the scanner at the bottom?

Numba (find_start)

```
@jit(int32(int32[:]), nopython=True)
def py_find_start(ranges: np.array) -> int:
    t_start = 0
    num_layers = len(ranges)
    while True:
        if check_capture(ranges, num_layers, t_start):
            t_start += 1
        else:
            break
    return t_start
```

Infinite loop

Did we get caught?

Break out if we didn’t get caught

Cython

Extended Python-like language

Compiles to C

Great for wrapping C libraries

Cython (check_capture)

```
@cython.boundscheck(False)
@cython.wraparound(False)
cdef bint check_capture(int[:] firewall, int num_layers, int t_start):
    cdef int pos, scanner_pos, scanner_range
    for pos in range(num_layers):
        if firewall[pos] != 0:
            scanner_pos = scanner_layer(firewall[pos], t_start + pos)
            if scanner_pos == 0:
                return False
    return True
```

turn off safety checks

types on everything

Results

	Time (milliseconds)
First Try	600,000
Second Try	6,000
PyPy	600
Numba	2
Cython	1

THANK YOU!!!

(tweet me: @jiffyclub)

1. Collect Data
2. Analyze
3. Experiment
4. GOTO 1

`github.com/jiffyclub/pycon-2018-talk`

http://www.pusheen.com/post/95781992231 https://imgur.com/t/pusheen/P1Fvz