Inside the New GIL

David M. Beazley
http://www.dabeaz.com

January 14, 2010
@chipy

What Happens at Chipy...

- ... gets people to go change Python
- In June, 2009, I gave that "Mindblowing GIL" presentation and said it would be cool for someone to hack on the problem
- Python 3.2 has a brand new GIL (implemented by Antoine Pitrou)
- Yay!

This Talk

- A very brief refresher on the old GIL
- An overview of the new one
- If you didn't see the previous talk, go to

  http://www.dabeaz.com/python/GIL.pdf

Disclaimer

- All of this is pretty bleeding edge
- I'm still working on a bunch of updated GIL benchmarks and other results in preparation for PyCON'2010
- So, this talk is rather preliminary... a preview perhaps.

Memory Refresh

- Python has the Global Interpreter Lock (GIL)
- It prevents more than one thread from running simultaneously in the interpreter
- On multicore, it has diabolical behavior
- Not only kills the performance of Python, but affects the performance of the whole machine due to all sorts of crazy system thrashing.

A Performance Test

- Consider this CPU-bound function

```
def count(n):
    while n > 0:
        n -= 1
```

- Sequential Execution:

```
count(100000000)
count(100000000)
```

- Threaded execution

```
t1 = Thread(target=count,args=(100000000,))
t1.start()
t2 = Thread(target=count,args=(100000000,))
t2.start()
```

Bizarre Results

- Performance comparison (Dual-Core 2Ghz Macbook, OS-X 10.5.6)

  Sequential : 24.6s
  Threaded : 45.5s (1.8X slower!)

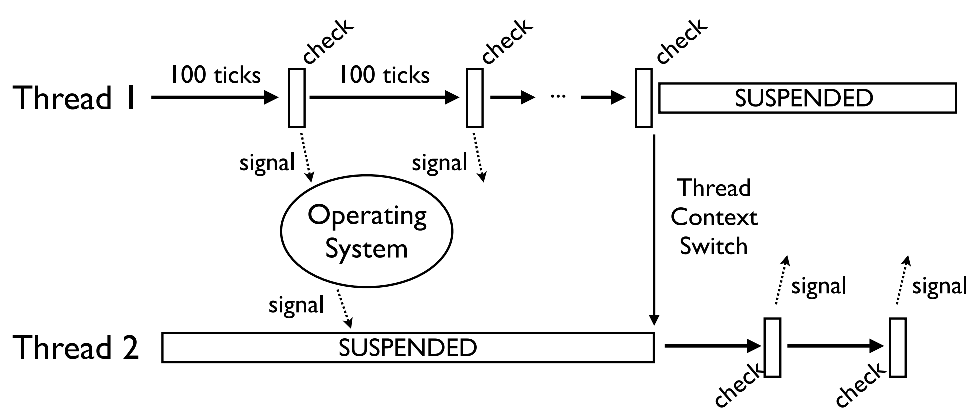
- If you disable one of the CPU cores...

  Threaded : 38.0s

- Insanely horrible performance. Better performance with fewer CPU cores? It makes no sense.

Thread Scheduling

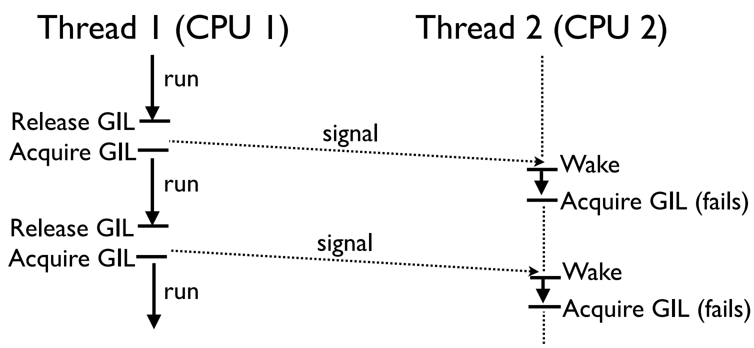
- The old GIL was entirely based on interpreter ticks and repeated signaling on a cond. var.



- All of that signaling is what kills performance

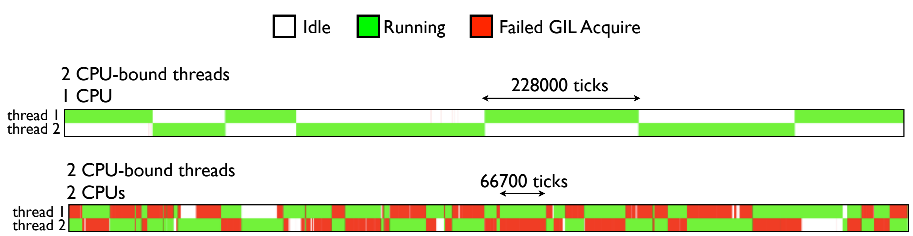
Multicore GIL Battle

- With multiple cores, CPU-bound threads get scheduled simultaneously (on different processors) and then fight it out



- The waiting thread (T2) may make 100s of failed GIL acquisitions before any success

GIL Battle (In Pictures)



Commentary: Even hard-core Python developers had no idea that this was going on with multicore

The New GIL

- First things first: The new GIL does not eliminate the GIL--it makes it better
- New implementation aims to provide more consistent runtime behavior of threads
- Namely, a significant reduction in all of that thrashing and extra signaling overhead

New GIL Explained

- The new GIL is still based on condition variables and signaling
- However, it's put together in an entirely different way
- Let's take a look

Interpreter Ticks - Gone

- Past versions of Python kept track of interpreter instructions and "ticks"
- Once a certain number of ticks had executed, a thread-switch signal was sent
- This is gone. There are no more ticks.
- sys.setcheckinterval() is gone too
- New GIL is time-based (more in a second)

New Thread Switching

- Decision to thread switch tied to a global var

```
/* Python/ceval.c */
...

static volatile int gil_drop_request = 0;
```

- A thread runs forever in the interpreter until the value of this variable gets set to 1
- At which point, the thread <u>must</u> drop the GIL
- Big question: How does that happen?

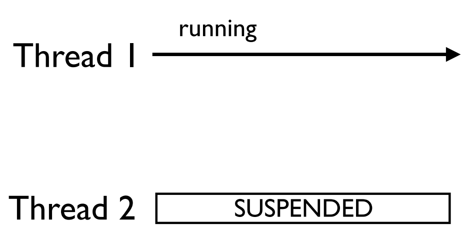
New GIL Illustrated

- In the beginning, there is one thread

- It runs forever
  - Never releases the GIL
  - Never sends any signals
  - Life is good

New GIL Illustrated

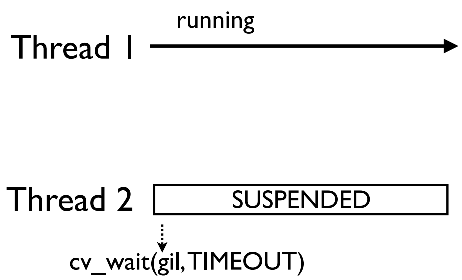
- Now, a second thread makes an appearance...



- It is suspended because it doesn't have the GIL
- Somehow, it has to get it from Thread 1

New GIL Illustrated

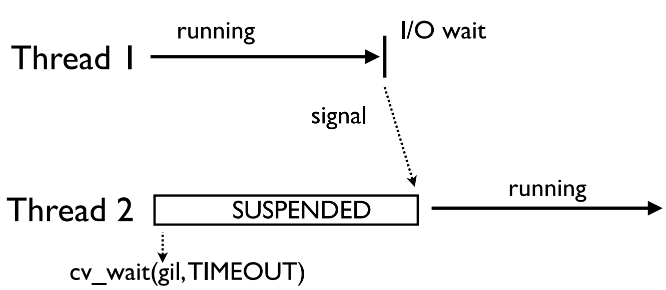
- Second thread does a timed cv_wait on GIL



- The idea : Thread 2 will wait to see if the GIL gets released voluntarily by Thread 1 (e.g., if Thread 1 performs I/O or goes to sleep)

New GIL Illustrated

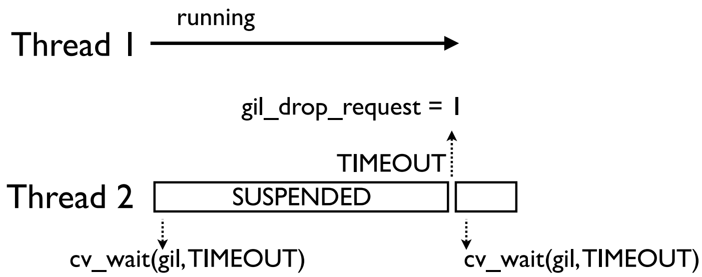
- Voluntary GIL release



- This is the easy case. Second thread gets signaled when Thread 1 sleeps. It runs

New GIL Illustrated

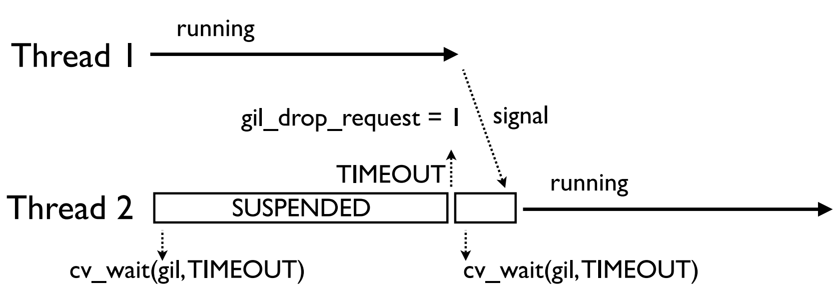
- Timeout causes gil_drop_request to be set



- After setting gil_drop_request, Thread 2 repeats its wait request on the GIL

New GIL Illustrated

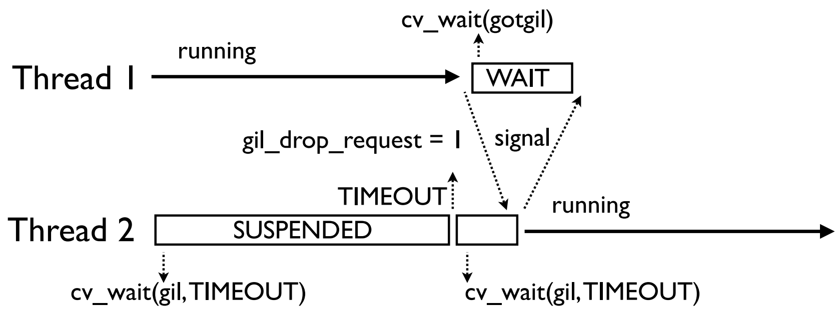
- Thread 1 is forced to give up the GIL



- It will finish its current instruction, drop the GIL and signal that it has released it

New GIL Illustrated

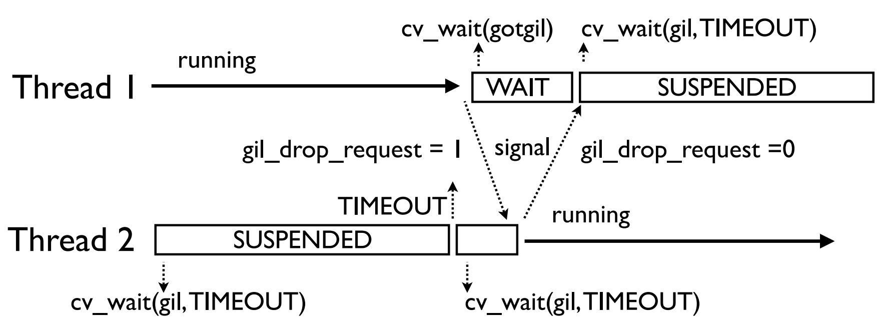
- On GIL release, Thread 1 waits for a signal



- Signal indicates that the other thread successfully got the GIL and is now running
- This eliminates the "GIL Battle"

New GIL Illustrated

- The process now repeats itself for Thread 1



- So, the sequence you see above happens over and over again as CPU-bound threads execute

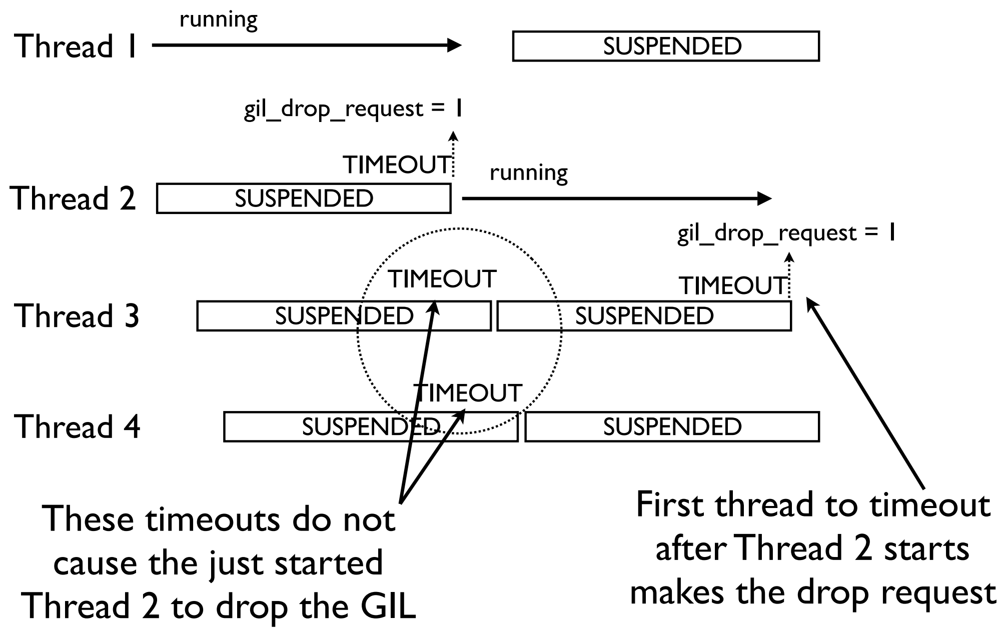
Default Timeout

- Default timeout for thread switching is 5 milliseconds (0.005s)
- By comparison, default context-switching interval on most systems is 10 milliseconds
- Adjust with sys.setswitchinterval()

Multiple Thread Handling

- On GIL timeout, a thread only sets gil_drop_request=1 if no thread switches of any kind have occurred in that period
- It's subtle, but if there are a lot of threads competing, gil_drop_request only gets set once per "time interval"
- You want this

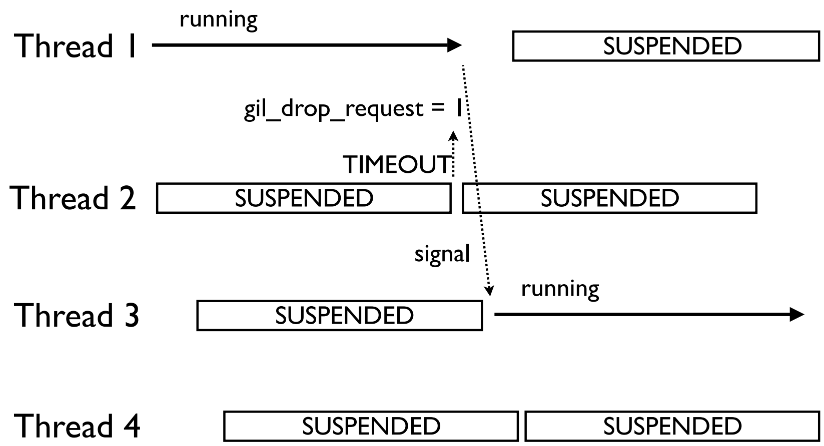
Multiple Threads



Multiple Thread Handling

- The thread that makes the request to drop the GIL is not necessarily the one that runs
- This is determined largely by OS priorities

Multiple Threads



- Here, Thread 2 made Thread 1 drop the GIL, but Thread 3 starts running (up to OS)

Does it Work?

- Yes, it's better (4-core MacPro, OS-X 10.6.2)

  Sequential : 23.5s
  Threaded : 24.0 (2 threads)

- Still working on some other tests (in preparation for PyCON), but it seems to be much better behaved--even if creating 100s of CPU-bound threads

Interesting Features

- The new GIL allows a thread to run for 5ms regardless of other threads or I/O priorities
- So, a CPU-bound thread might block an I/O bound thread for that amount of time
- This is probably what you want to avoid excessive thrashing/context switching
- Be aware that it might impact response time (so you may want to adjust the interval)

Interesting Features

- Long running calculations and C/C++ extensions may block thread switching
- Thread switching is not preemptive
- So, if an operation in an C extension takes 5 seconds to run, you will have to wait that long before the GIL gets released (same was true of old GIL)

Final Comments

- New GIL probably needs further study
- Seems good. Need to investigate behavior under heavy I/O processing
- Again, only implemented in Python 3.2 which is only available via svn checkout
- Backport to Python 2.7? (Don't know)