Performance

What is performance

- The degree to which the system is able to meet its throughput and/or latency requirements in terms of the number of transactions per second or time taken for a single transaction

Multithreading

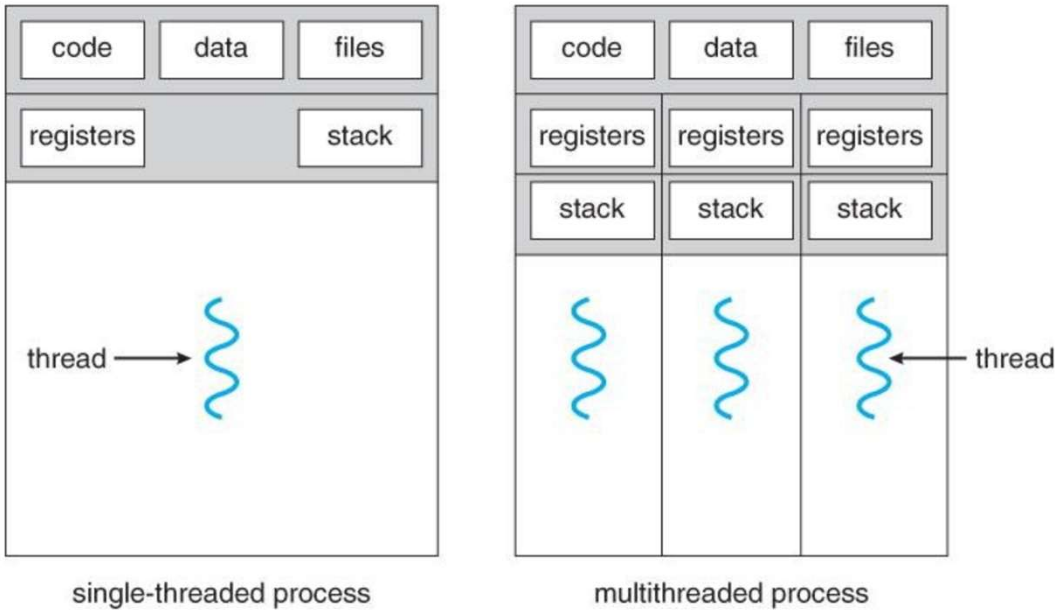
Types of threads

- User-level threads (Python works at this level)
  - Threads we actively create and run for all of our tasks
- Kernel-level threads
  - Very low-level threads acting on behalf of the operating system

Threads compared with Processes

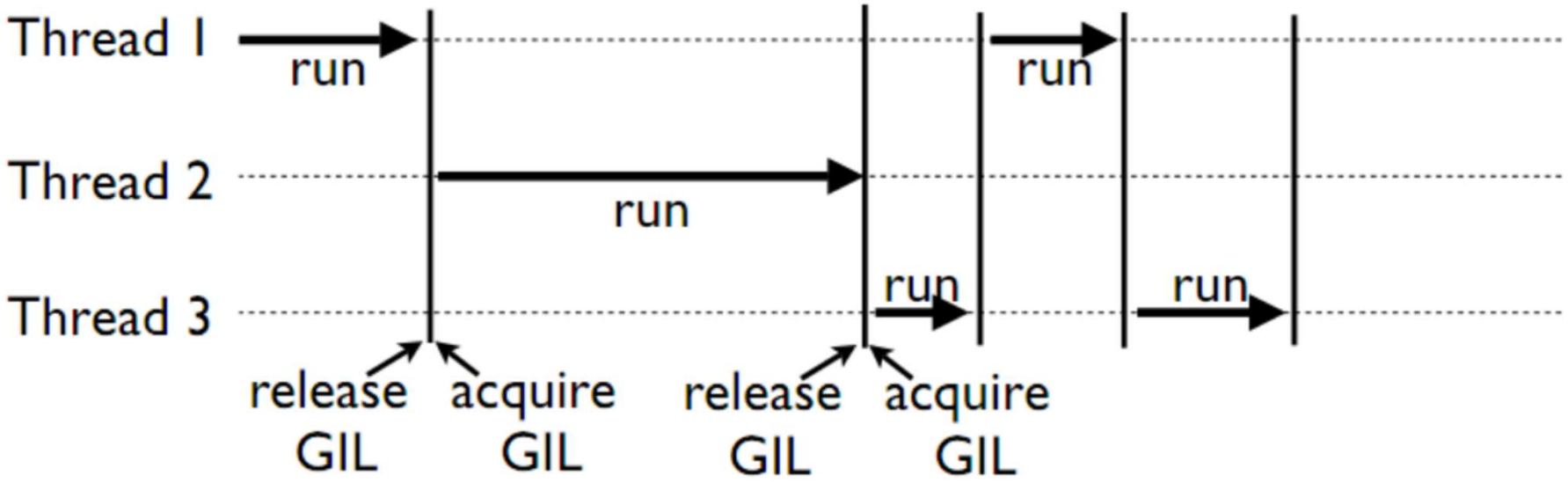
- Processes are very similar in nature to threads
- Key advantage is that they are not bound to a singular CPU core

Single or multiple threads



The limitations of CPython

- The Global Interpreter Lock (GIL) is a mutual exclusion lock (mutex) which prevents multiple threads from executing CPython code in parallel



Global Interpreter Lock (GIL) in CPython

- The GIL prevents multiple native threads from executing byte codes at same time
- Necessary mainly because the memory management in CPython is not thread-safe
- Other features have grown to depend on the guarantees that the GIL enforces
- GIL is a bottleneck
  - Prevents multithreaded Python programs from taking full advantage of multiprocessor systems
  - Potentially blocking or long-running operations such as I/O, image processing and NumPy operations happen outside the GIL

GIL degrades performance

- System call overhead is significant especially on multicore hardware
  - Two threads calling a function may take twice as much time as a single thread calling the function twice
  - Can cause I/O-bound threads to be scheduled ahead of CPU-bound threads
  - Prevents signals from being delivered
- To minimize the effect of GIL on performance call the interpreter with the -O flag
  - Generates an optimized bytecode with fewer instructions and less context changes

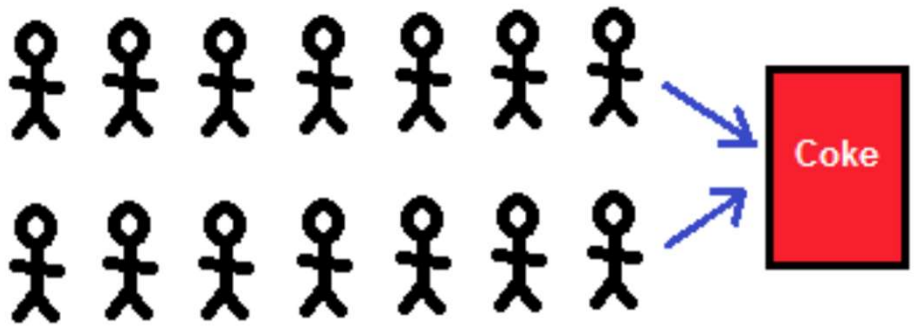
Other Pythons

- Other implementations of Python, such as Jython and IronPython don’t feature any form of Global Interpreter Lock
- They can fully exploit multiprocessor systems
- Jython
  - An implementation of Python that works directly with Java
    - CPython’s single-core execution typically outperforms Jython and its multicore approach
    - Jython outperforms CPython when working with large datasets
- IronPython
  - Works on top of .NET framework

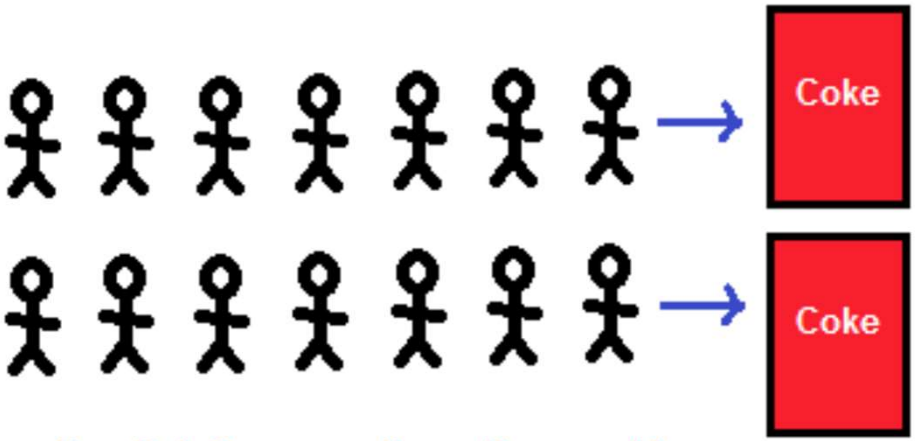
Threads

- Multiple executions in the same process
  - parallelism within a process
- A thread has its own stack
- Each thread shares
  - Heap
  - Static data
  - Process resources (open files etc.)
- Thread scheduling is performed by kernel
  - co-operative
  - pre-emptive

Concurrency and Parallelism



Concurrent: 2 queues, 1 vending machine



Parallel: 2 queues, 2 vending machines

Reasons to use Multi-threading

- Complex applications may need to perform parallel tasks
  - updating graphical information
  - waiting for user input
  - Reading/writing data via sockets
  - performing call-back operations
- Single threaded programs
  - each task runs sequentially
  - tasks cannot run at the same time
  - Can be inefficient
- Multithreaded programs
  - each task can run in parallel
  - harder to program
  - Often more efficient

Thread Objects

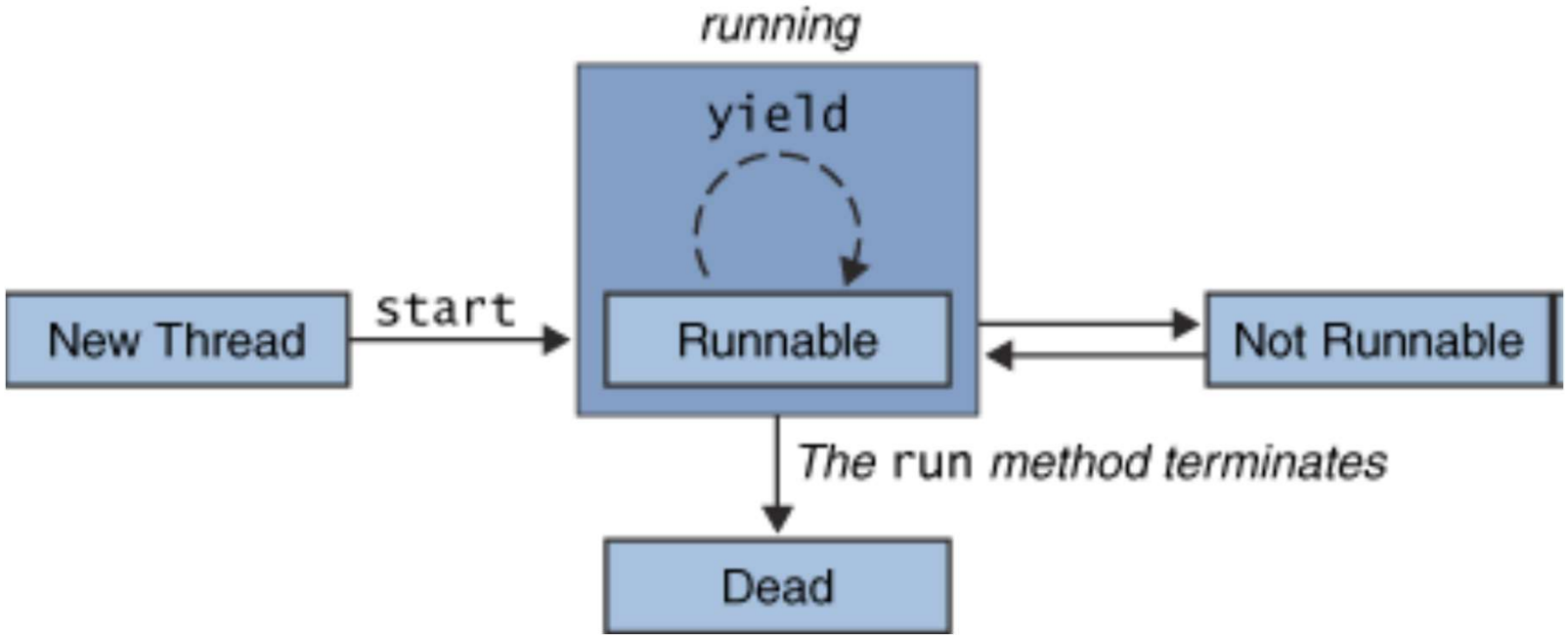
- A thread object represents a thread
  - A thread object is not the same as the thread
  - A thread object is a helper object
- Thread Objects have methods to facilitate thread management
  - Invoke thread object methods by the calling thread
  - Usually only the run() method is executed by the new thread

Thread class definition

```
# Python Thread class Constructor
def __init__(self, group=None, target=None, name=None,
             args=(), kwargs=None, verbose=None):
```

- Constructor takes five real arguments
- group
  - reserved for future extension
- target
  - The callable object to be invoked by the run() method
- name
  - The thread name
- args
  - The argument tuple for target invocation
- kwargs
  - A dictionary of keyword arguments to invoke the base class constructor

Thread Life-Cycle



Invoking Threads

- Use Thread class in the threading module
  - threads have no priorities
  - runs to completion
  - cannot be suspended
- Threading strategies
  - New thread executes a call-back managed by the Thread class
    - The call-back can be a function or a class with __call__()
  - Derive from Thread class and define a run() method for the thread to execute
- Callable classes are the most flexible
  - you can pass parameters to the new thread
- Call-back function are the simplest

Thread Locking

- Locks are recommended when using threads
  - always release locks in a finally block in case an exception occurs
    - Using the ‘with’ construct does this automatically
- Shared resources should be locked for increased reliability

Thread Re-entrant-locks (Rlocks)

- Synchronization primitives
  - like standard locks
  - can be acquired by a thread multiple times if that thread already owns it

Thread Events

- Use event objects as signals
  - Thread can wait() on signal
  - Another thread can set() the signal

Thread Semaphores

- Semaphores provide a shared lock
  - define a count
    - Number of threads given simultaneous access to a resource
    - Count is decrement each time semaphore acquired

Immutable Objects

- An object is immutable if its state cannot change after it is constructed
  - A very good strategy for creating reliable multi-threaded code
  - Since they cannot change state they cannot be corrupted
  - No need to use locks