High Performance Python Lab

Overview of multithreading and multiprocessing tools

November 22, 2023

Difference between multithreading and multiprocessing

Multithreading:

+ less overhead

• common address space

- need to synchronize access to resources

+ easy to communicate with others

Multiprocessing:

- more overhead

• independent address spaces for each process

+ less need to synchronize

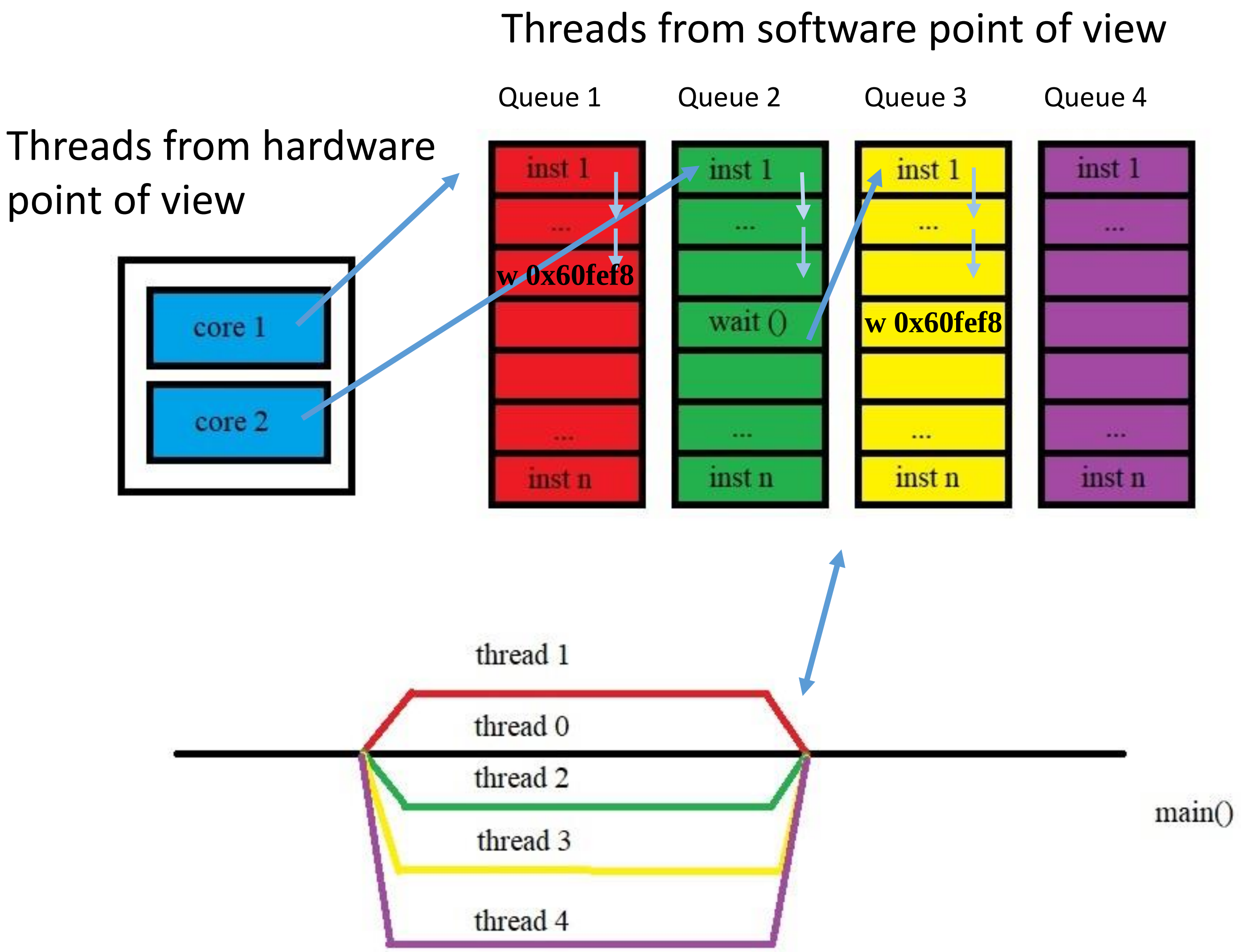
- need to find ways to communicate with others

Overview of libraries

- Multithreading
- Multiprocessing
- Concurrent
- Joblib

Also: Dask, ray, asyncio

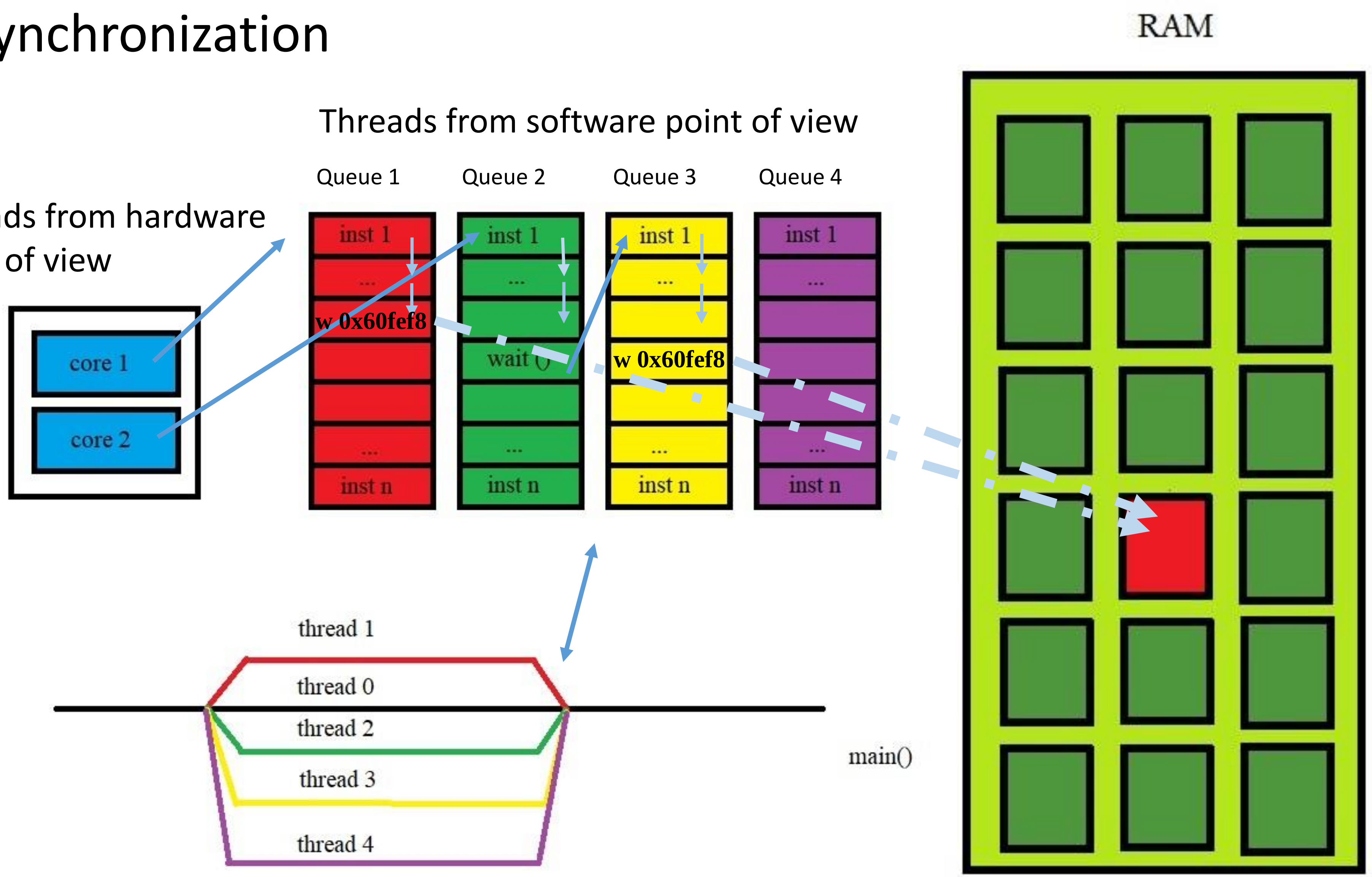
Synchronization



Synchronization

Threads from software point of view

Threads from hardware point of view



Data access needs to be synchronized

Synchronization techniques

Busy waiting – repeatedly check some condition. Once it's true you can modify some shared variable.

Mutex – a technique of allowing only one thread to access a variable at a given point in time using locks. Once a thread **acquires the lock** the shared variable cannot be accessed by other threads.

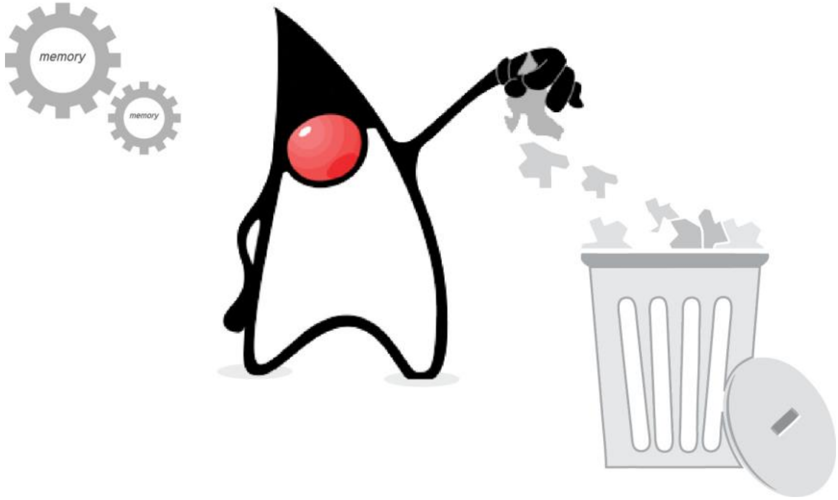
Semaphore – a generalization of mutex. When acquiring the lock semaphore decrements the counter. Once the counter gets to zero other threads have to wait while others unlock the semaphore.

Model examples

Pipeline – if process can be broken down into stages of a single pipeline independent parts can be done in parallel. Or they can be done in parallel on different data (**query processing, web server administration**).

Background Task – a thread running in the background doing "menial" jobs (**back up data, collect garbage**).

User interface – GUI use multithreading to ensure responsiveness of the interface to the user (**progress bars, loading animation**).



Semaphore use case description

Web application:

- it has to process incoming requests from users. Seeing as these requests are independent the processing can be done simultaneously i.e using threads.

- there are millions of requests and the server can only provide a hundred of threads. There is no way this number of threads can deal with such number of requests in a runtime fashion.

- that is why the requests need to be queued up. To do that the servers have queuing threads.

- the length of the queue is limited by the memory.

Implementation

The model for the case is called **Consumer-Producer model**. And this is a typical use case for semaphroes.

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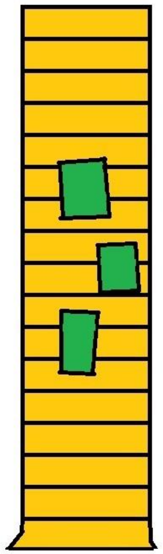

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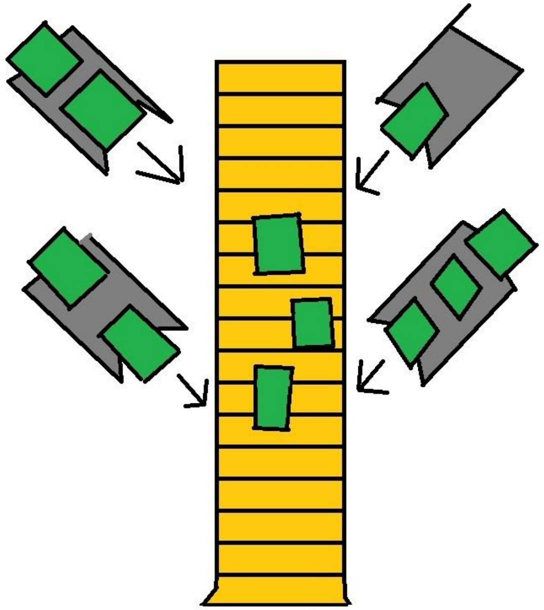

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2) Producer/s – thread/s that try to fill the queue

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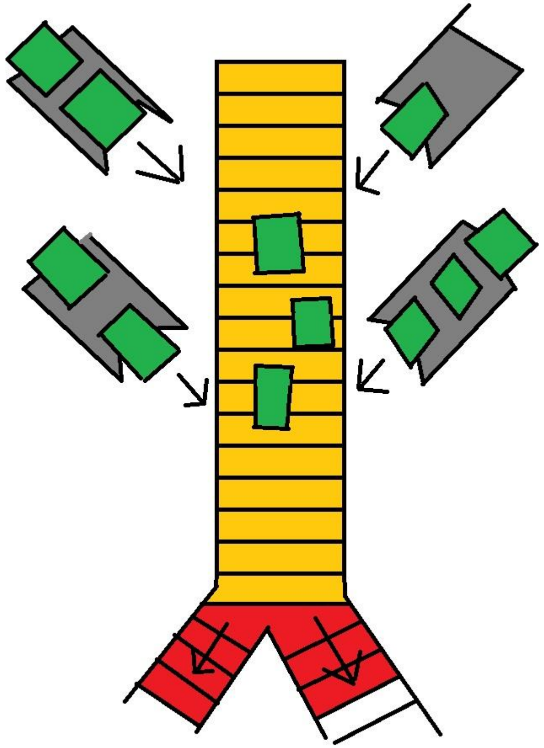

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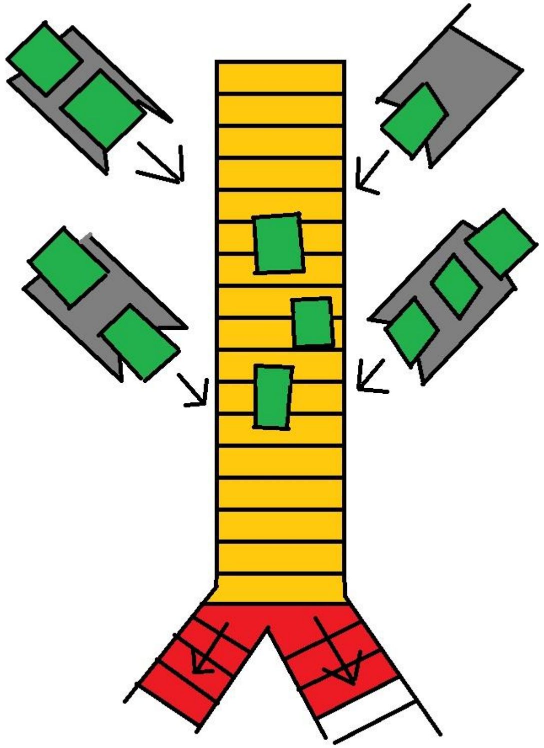

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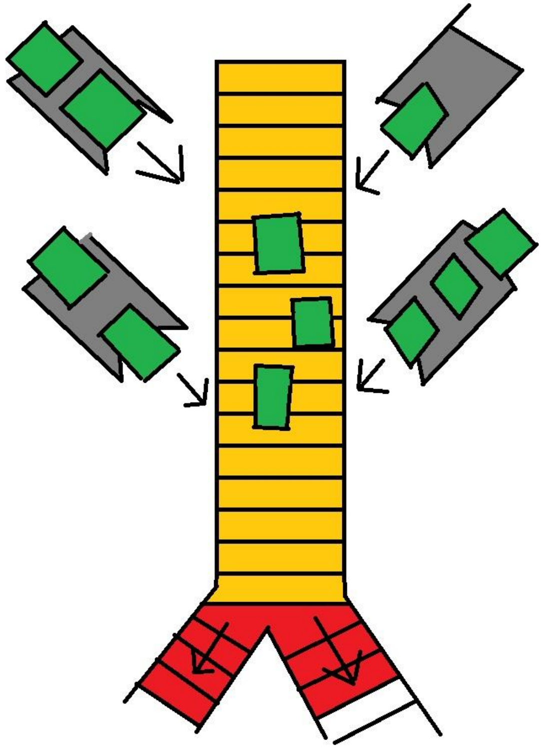

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1) Semaphore to protect queue size going over capacity
2) Semaphore to protect queue size going negative

Global interpreter lock (GIL)

Python code is interpreted line by line. In a multithreaded program the interpreter is locked by a single thread. This is needed to avoid segmentation faults.

Hence multithreading can’t properly help with performance if the code needs constant interpretation – **CPU bound programs**.

Alternatively, if the program needs significant amount of time to carry out the already interpreted instruction (**I/O calls**, for instance) then GIL less of an issue

Practice session

1) Introductory examples
2) Multithreading/multiprocessing with Python on more realistic use cases
3) Little bit of practice

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Conclusions:

1) If the program/function occasionally lets go of the CPU then GIL is less of a problem
2) Multiprocessing adds time overhead on creating and destroying processes
3) Multithreading and multiprocessing add memory usage load
4) Popular libraries (scikit, torch, numpy etc.) usually have multiprocessing/multithreading modules already implemented

Multiprocessing/multithreading inside libraries

Numpy:
- Blas and Lapack via Cython
- ...

Pytorch:
- OpenMP and TBB via Cython
- JIT compilation
- ...

Scikit:
- joblib
- ...