



ADDRESSING MULTITHREADING AND MULTIPROCESSING IN TRANSPARENT AND PYTHONIC METHODS

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Overview

- State of current concurrency and parallelism
- Nested parallelism and oversubscription
- A few composable methods of thread control
- How it works under the hood (*tbb*, *smp*)
- Pythonic style?
- Future of Pythonic style for parallelism
- Summary

Current State of Python concurrency and parallelism

- The Python ecosystem has had quite a few cool developments over the last few years:
 - *Threading library* (2008)
 - *Multiprocessing* (2008)
 - *Twisted* (2008)
 - *Concurrent futures* (2009)
 - *Cython* (2009)
 - *Tornado* (2010)
 - *Numba* (2012)
 - *Asyncio* (2013)
 - *Dask* (2015)
 - *Trio* (2017)

Current State of Python concurrency and parallelism

- The options in this space are *very good* compared to other ecosystems
- Majority do a good job of playing nicely with the *Global Interpreter Lock* (GIL) or walk around it with *distributed* or *vectorization techniques*
- In more domain specific areas, one can rely on high-end C libraries that have threading to harness parallelism (SciPy/NumPy)
- Recent trends have Python accessing increasing core count machines (from 2-4 to over 28 core) as commonplace
 - *Nested parallelism and oversubscription* now quite possible in kernels

The Safety of the GIL

- The GIL has been complained about by many in the Python space
- Many efforts have been made to try to remove the GIL
- As it stands, some of the main tenants of what guarantees the GIL provides are hard to ignore
 - *Read/write safety for Python Object access*
 - *Predictable behavior*
 - *Ensure reference counting doesn't get hosed*
 - *Makes extension module development easier (and removes the undue burden on developers)*

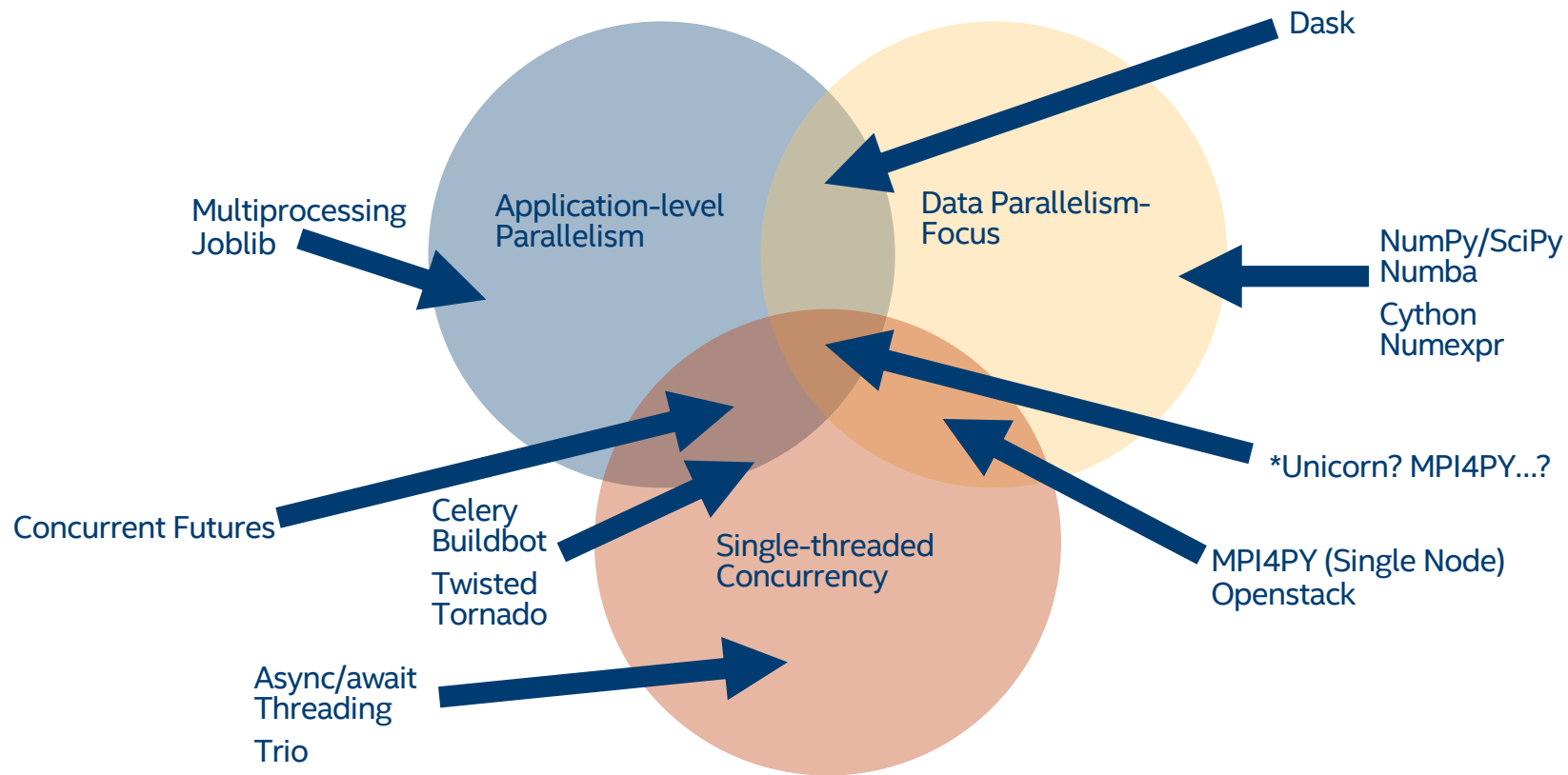
The Safety of the GIL (con't)

- In reality, **the GIL is a non-issue** as many have found ways of stepping around the GIL
- *SciPy* and *NumPy* are great examples—once a command is sent to SciPy, it gets dispatched where BLAS implementations like MKL and OpenBLAS are vectorized and parallelized
- Other frameworks directly access vectorization and exit the Python+GIL layer to utilize threads—*Numba*, *Numexpr*, *Cython* do this
- *Multiprocessing* frameworks can escape it via a separate process, which can also have separate threads

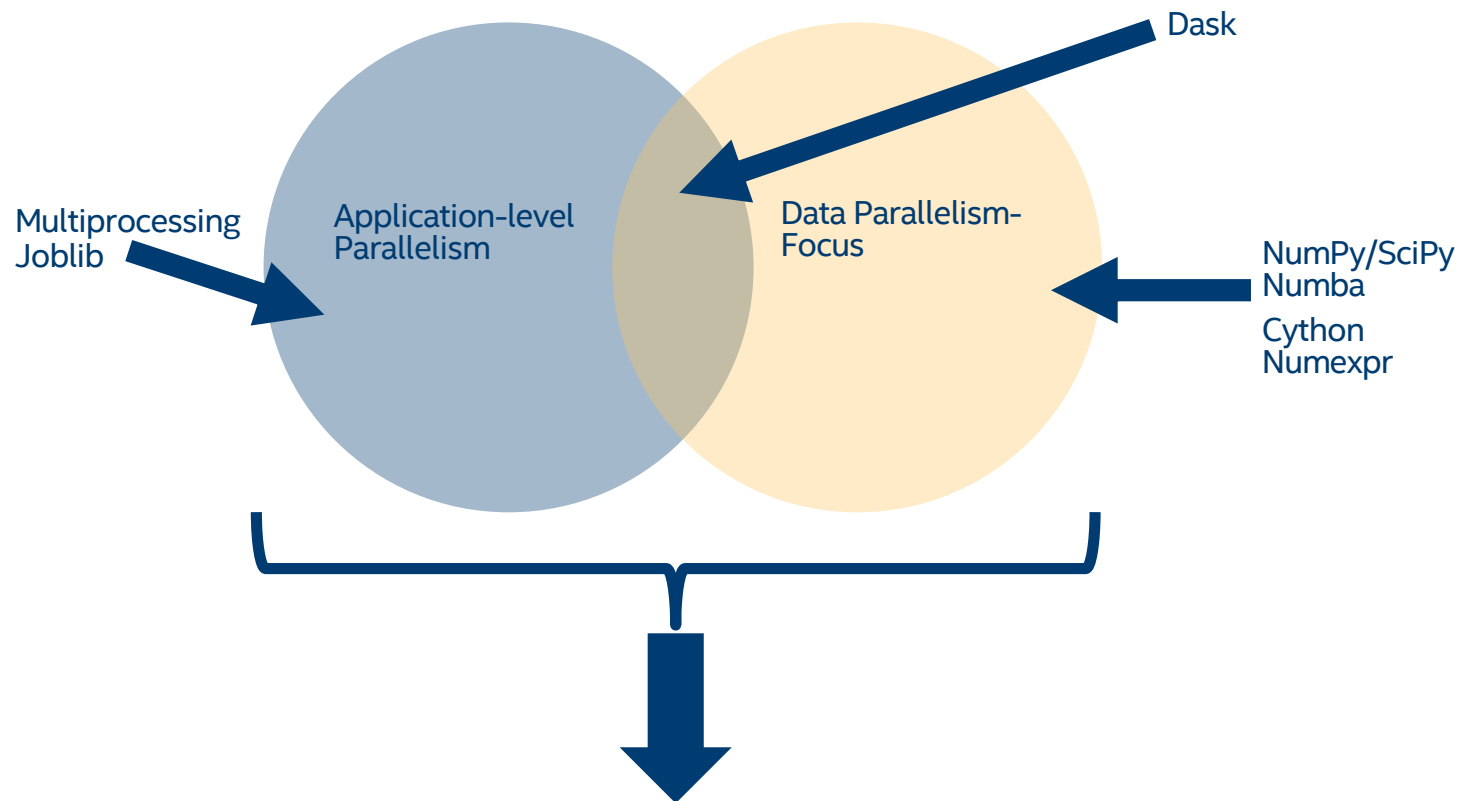
The Safety of the GIL (con't)

- Exiting the GIL with a C library is the generally the most Pythonic-ish way of doing things (as it encompasses the abstraction of a known computational flow)
- Composition of abstracted flows also works (splitting off into multiple processes)
- It is quite rare to absolutely necessitate a language to be completely thread safe; many of the advantages of Python would go away

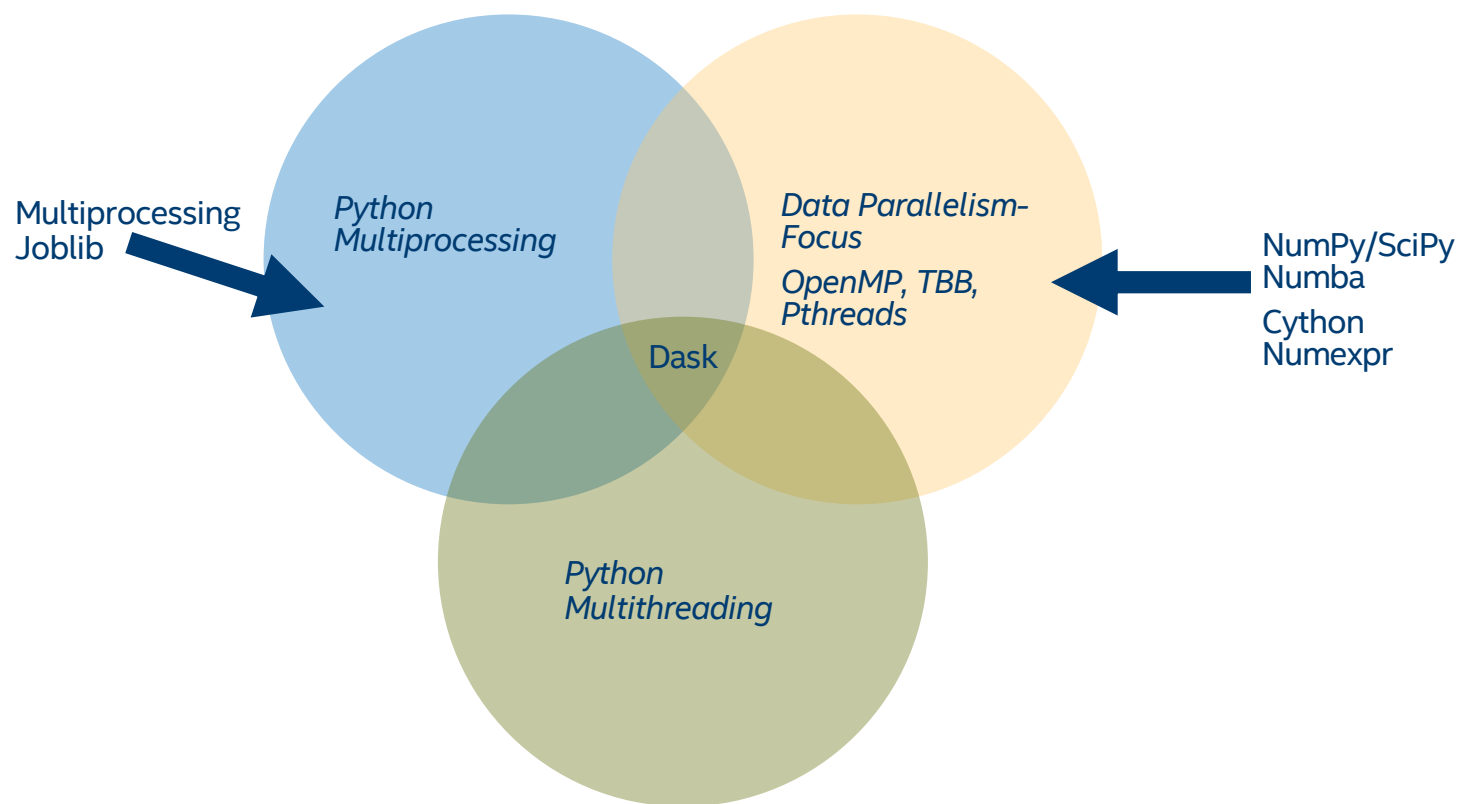
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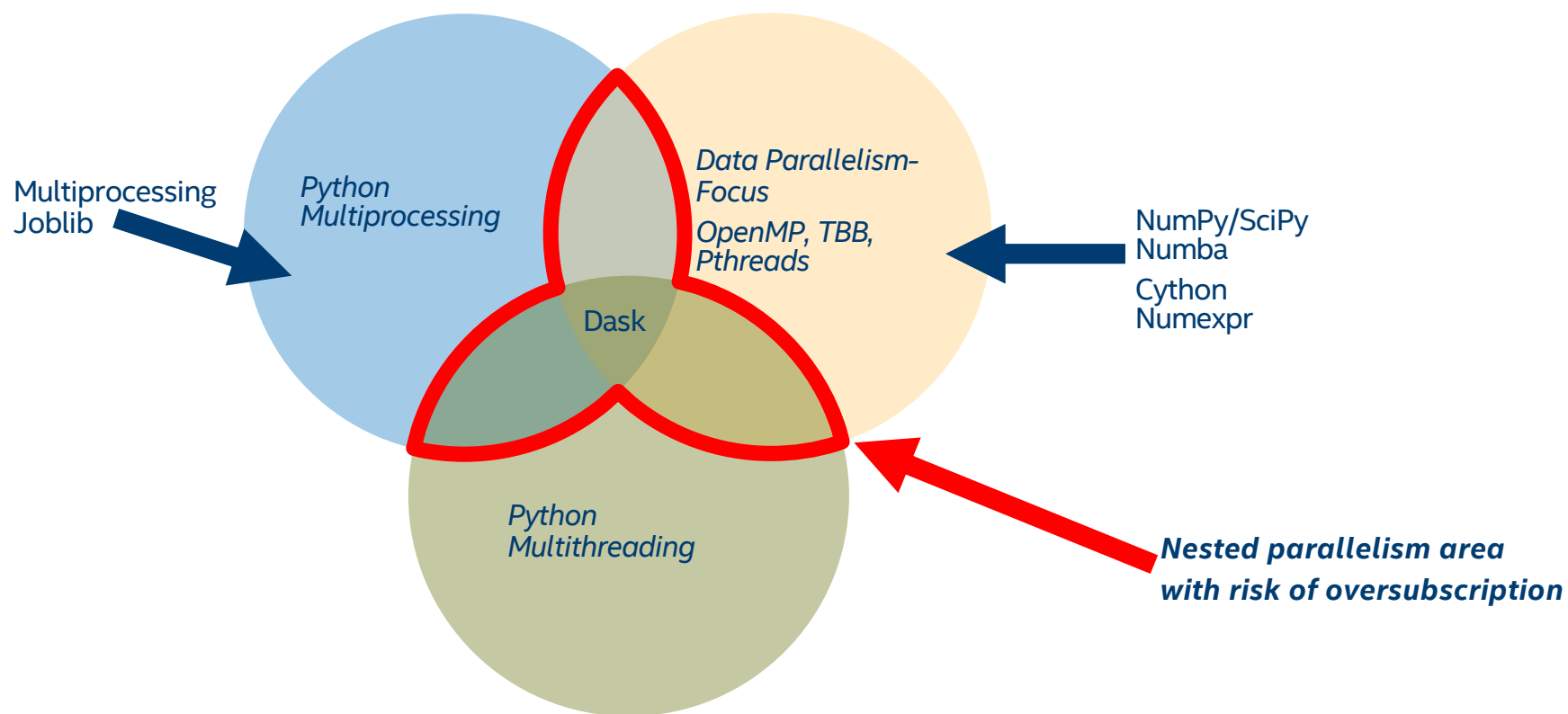
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The spaces covered



Nested parallelism

```
data = numpy.random.random((256, 256))
```

```
pool = multiprocessing.pool.ThreadPool() # creates P threads
```

```
pool.map(np.linalg.eig, [data for i in range(1024)])
```



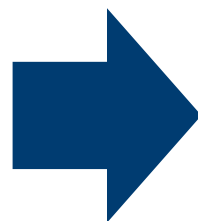
P Python threads * P NumPy → MKL → OpenMP threads = P^2 threads total

Oversubscription

P software threads



$P \times P$ threads



Oversubscription overheads

- Types of impact
 - Direct OS overhead for switching out a thread
 - CPU cache becomes cold: invisible impact
 - Other threads are waiting until the preempted one returns
- *Tensorflow, Scikit-Learn, PyTorch* have a recurring battle with these
- How do they solve it?
 - Most use `OMP_NUM_THREADS=1... KMP_BLOCKTIME=1...`
 - SMP ironically addresses this (more on this later)

Introducing composability modules

- **tbb4py: Intel TBB for Python**
 - A Python C-extension package managing nested parallelism using dynamic task scheduler of Intel® Threading Building Blocks library
 - Instantiates via monkey patching of Python's pools and enabling TBB threading layer for Intel® MKL (no code changes required)
 - Dynamically maps tasks onto coordinated pool(s) to avoid excessive threads

Introducing composability modules

- **smp: Static Multi-Processing**
 - A Pure Python package managing nested parallelism through coarse-grain static settings
 - Instantiates via monkey patching of Python's pools (no code changes required)
 - Utilizes affinity mask + OpenMP settings to statically allocate resources and avoid excessive threads

Nested parallelism (again)

```
data = numpy.random.random((256, 256))
```

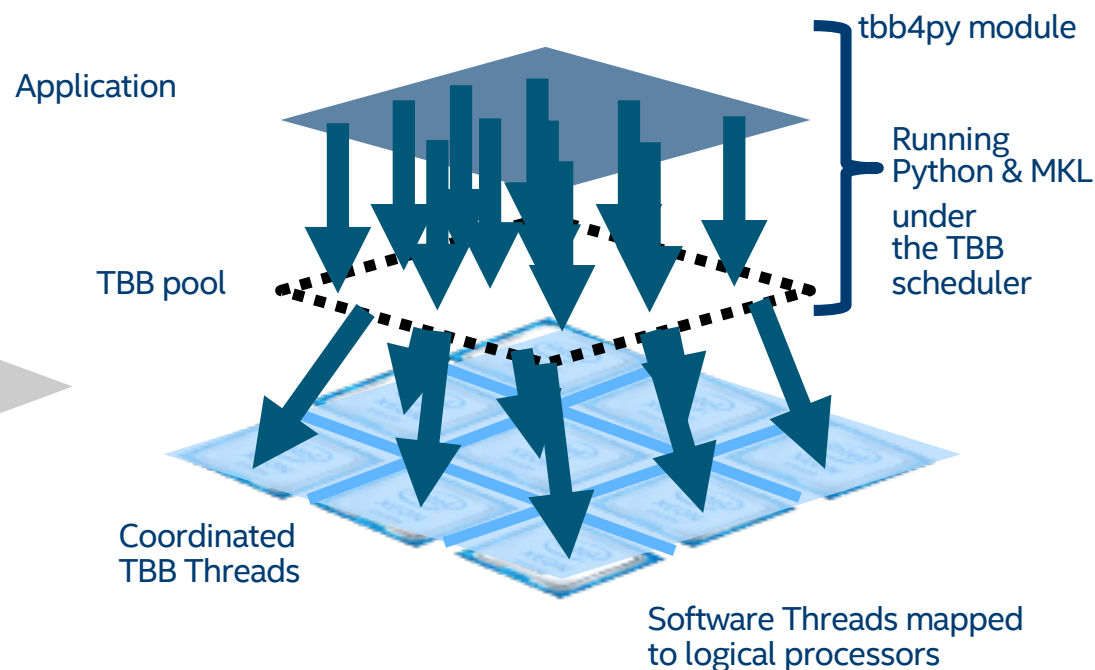
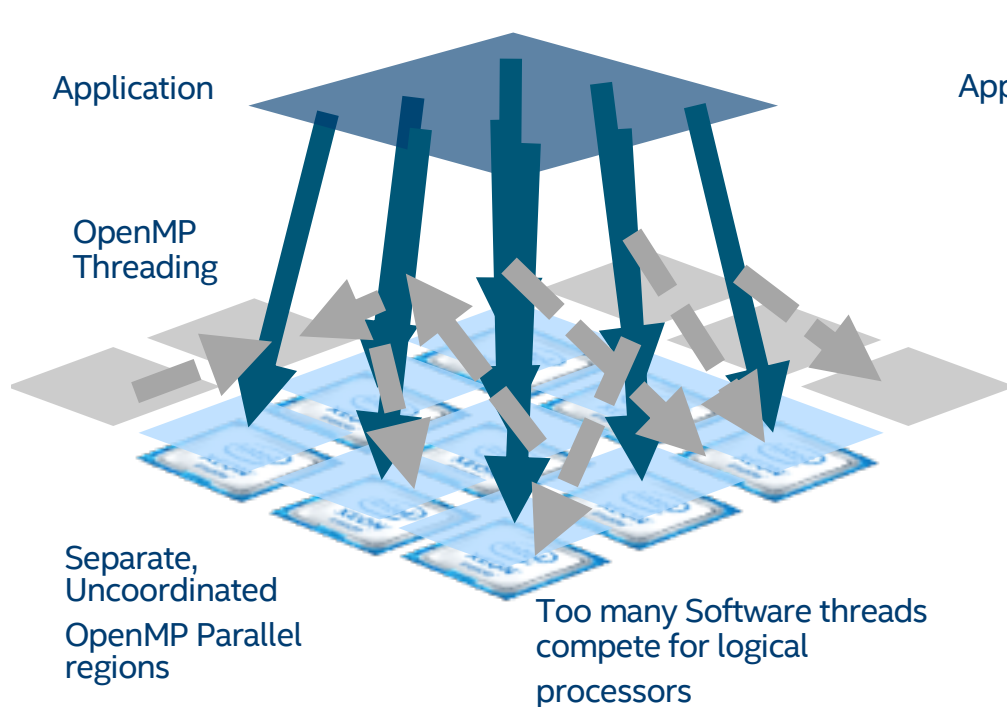
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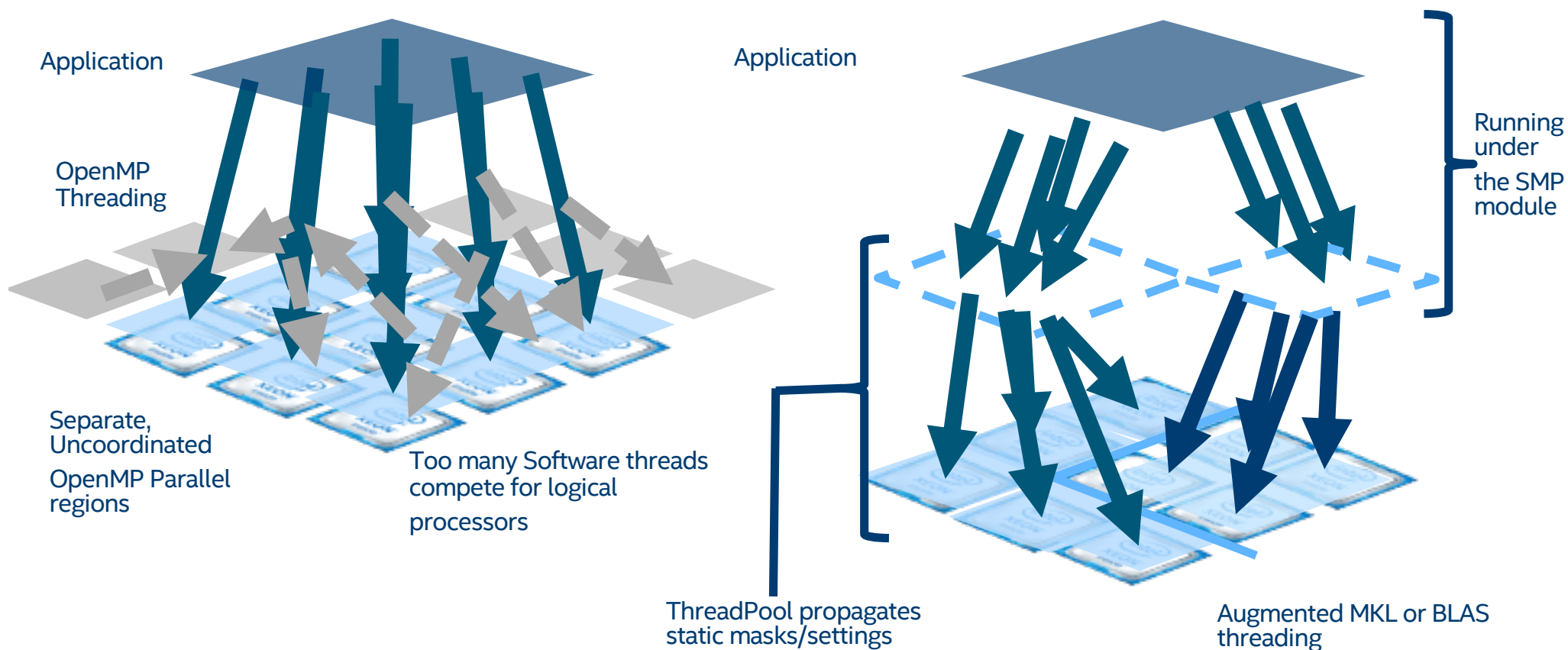


P Python threads * P NumPy \rightarrow MKL \rightarrow OpenMP threads = P^2 threads total

TBB's Thread coordination system



SMP's total threading affinity system



DEMOS

Repository:

https://github.com/IntelPython/composability_bench/tree/master/scipy2018_demo

Current State of Python concurrency and parallelism (slight return)

- Much of the **concurrency and async areas** are rich with packages that help solve the needs of the majority of Python users
- True Parallelism is a small but strong area, so focus has generally been towards concurrency + async offerings
- Most ways of achieving parallelism in this area rely on *vectorization frameworks* or with multiprocessing or distributed
- How does one do so in a **semi-pythonic** way?

Pythonic-ish?

- Relatively few code changes
- Modify current behavior of a framework to fit one's needs (or prevent a massive rewrite)
- Directly in the Python std library
- Writable from the Python layer
- Easy interface to understand
- Keeps one in the Python layer (and does not drop to an IR)

How close can we get?

Pythonic-ish?

(tbb4py)

- ✓ Relatively few code changes
- ✓ Modify current behavior of a framework to fit one's needs (or prevent a massive rewrite)
- ✗ Directly in the Python std library
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Pythonic-ish?

(smp)

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Pythonic-ish style for parallelism?

- How realistic is it to have a firm requirement for a Pure Python implementation?
- What is the best way to modify Python code? Monkey patching? New framework?
- At what level should the parallelism be controlled?
- Can an interface be agreed upon to operate on parallelism? (such as concurrency's concurrent futures)

Pythonic-ish style for parallelism? (con't)

- How realistic is it to have a firm requirement for a Pure Python implementation?
 - Not required, but highly recommended
- What is the best way to modify Python code? Monkey patching? New framework?
 - Monkey patching is seeming to be the new normal

Pythonic-ish style for parallelism? (con't)

- At what level should the parallelism be controlled?
 - Python layer-sort of? It should have directives for how additional layers can compose it as the best case
- Can an interface be agreed upon to operate on parallelism? (such as concurrency's concurrent futures)
- Jury is still out on this one, but with every iteration of attempts (like *smp*) we get a more clear picture

Summary

- **tbb4py** and **smp** attempt to address Pythonic-ish methods by attempting to *augment* the way we use multithreading and multiprocessing (attempting to not change underlying code)
- It is best to leave the two forms of multiprocessing and multithreading at their same levels—Python level and C level, respectively
 - Most multithreading is domain specific it needs to be in C, so it would need to be written in C or generated (like Numba, numexpr, Cython)
 - Perhaps leaving threading and multiprocessing directives as a file or comments might be better... but doesn't that just sound like `#pragma omp`?

Summary (con't)

- Having more “augmentable” threading behavior is more useful, but that means putting the bulk of the responsibility on the users themselves
- Threading for numerical has lots of known frameworks, proper threading from non-numerical may be possible but will require stricter typing than just “Python Object”
 - At that point... why are you using Python, right? Flexible vs. Strict
- The Python ecosystem has a critical mass of good frameworks looking to address multithreading and multiprocessing—so for those of you working in it, keep going!

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