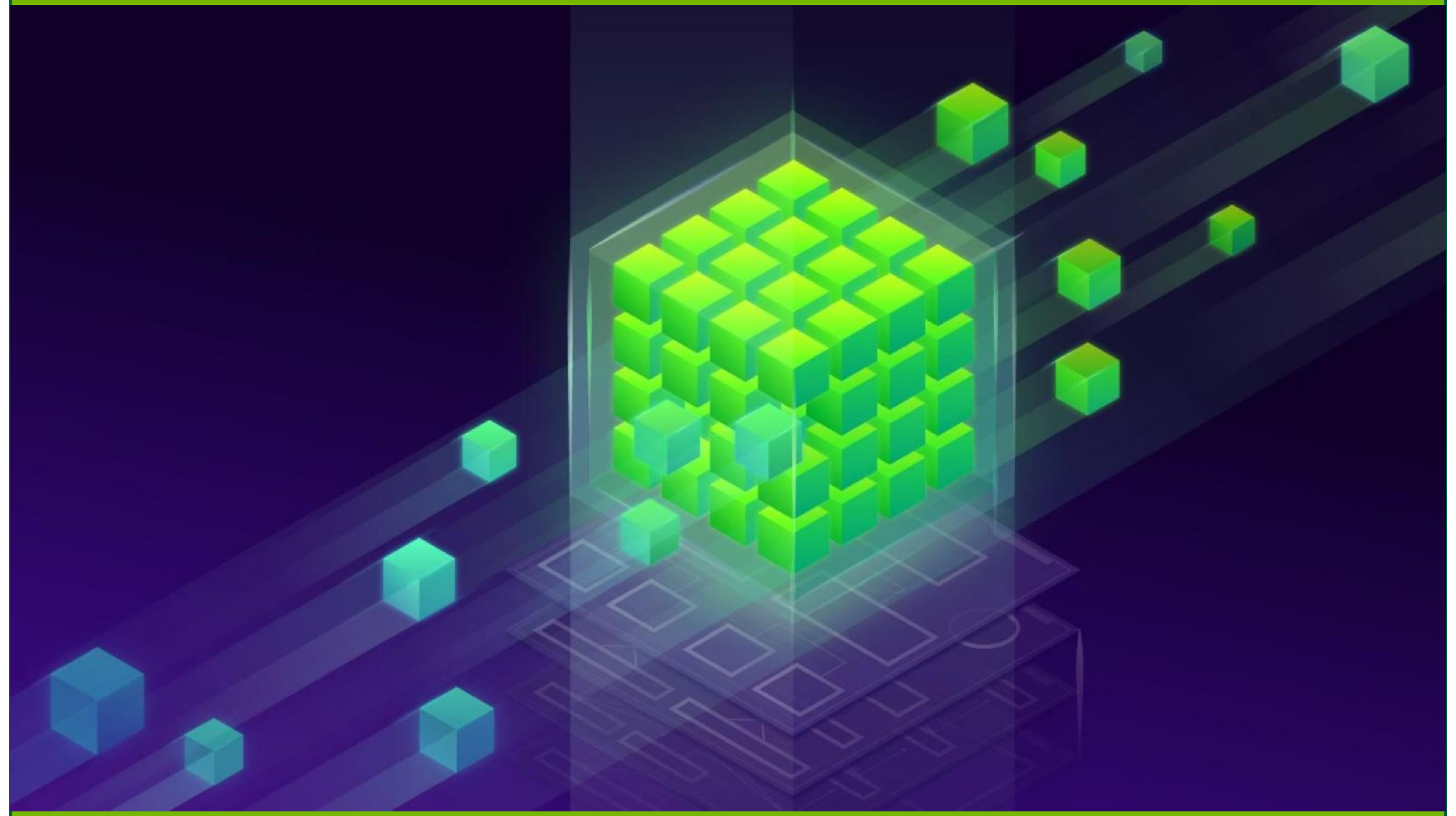
# High-Performance CUDA Ops in Python: JIT-Compiling CCCL with cuda.compute



https://github.com/NVIDIA/cccl/

## CUDA Core Compute Libraries for Python

### What is it?

`cuda.compute` is a Python package that brings composable, high-performance CUDA algorithms to arrays, tensors, and data ranges (iterators). It fills the missing middle layer: optimized GPU kernels that act as reusable building blocks, making it easy to write efficient algorithms—without needing deep CUDA expertise.

### Who is it for?

Python developers who want to write custom algorithms portable across GPU architectures without dropping down to CUDA C++.

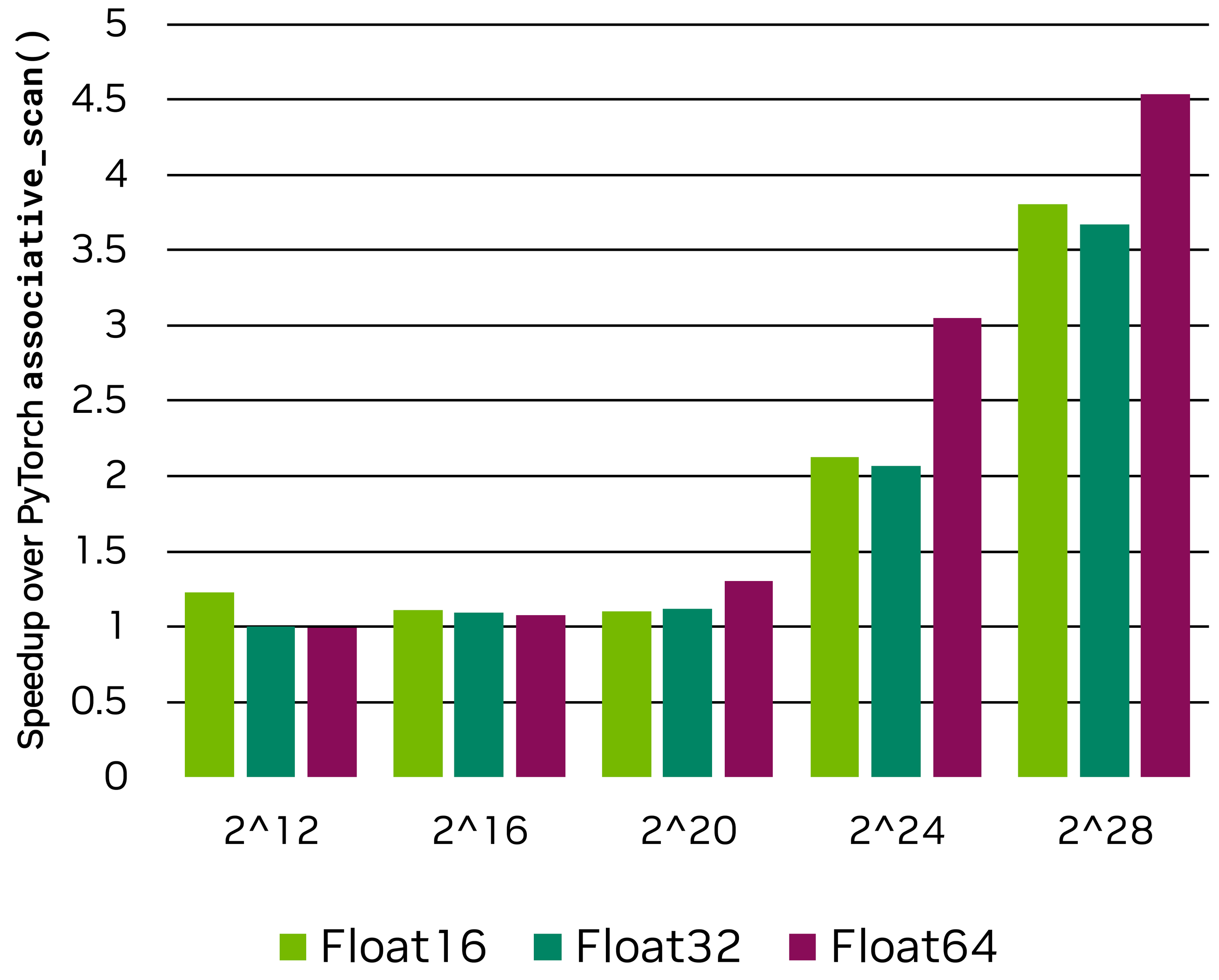
## Build PyTorch ops in pure Python

### Faster than `torch.compile()`

PyTorch recently introduced the higher order operator `associative_scan` that computes a parallel prefix scan over an input tensor with a user-provided associative operator.

We implemented `associative_scan` entirely in Python with no C++ code using cuda.compute's `scan`. We compared our implementation's performance to the existing PyTorch implementation compiled with `torch.compile()`. Benchmarks showed that our implementation achieves up to a 5x speedup.

`cuda.compute` offers speed-of-light performance and flexibility through Python defined operators and custom datatypes, making it ideal for developing PyTorch operators.




## CCCL Tops GPU MODE Leaderboard

GPU MODE

Simple Python implementations based on `cuda.compute` top the GPU Mode leaderboard. `cuda.compute` achieves performance on par with CUDA C++, i.e., state-of-the-art performance across GPU architectures.

| | H100 | A100 | L4 | T4 |
|---|---|---|---|---|
| `grayscale` | 10th | N/A | N/A | N/A |
| `histogram` | 1st | 1st | 1st | 4th |
| `prefixsum` | 1st | 1st | 1st | 1st |
| sort | 1st | 1st | 1st | 1st |
| `vectoradd` | 1st | 1st | 1st | 1st |
| `vectorsum` | 2nd | 2nd | 4th | 2nd |

## Speed of Light Algorithms, no manually written CUDA kernels

```python
import cuda.compute
import torch

# Scan algorithm showcasing iterators, custom operators, and kernel fusion

# Create a counting iterator to represent the sequence 1, 2, ... N
counts = cuda.compute.CountingIterator(1)

def square(x):
    return x * x

# Create a transform iterator to represent the sequence 1, 4, 9, ... N^2
input = cuda.compute.TransformIterator(counts, square)

# Create an output array to store the result
output = torch.empty(2**20, dtype=torch.int64).cuda()

def add(a, b):
    return a + b

# Perform the scan
cuda.compute.inclusive_scan(input, output, add, init=0, num_items=output.size())

# Merge sort algorithm showcasing a custom datatype to be used as input to sort
@cuda.compute.gpu_struct
class Pair:
    a: torch.int16
    b: torch.float64

# Prepare sample input
a_keys = torch.tensor([3, -1, 3, 0, -1, 2, 0], dtype=np.int16).cuda()
b_keys = torch.tensor([1.5, 2.3, 0.5, 9.5, -7.0, 4, -1.0], dtype=torch.float64).cuda()
keys = cuda.compute.ZipIterator(a_keys, b_keys)

# Struct-aware comparator
def compare_op(lhs: Pair, rhs: Pair):
    return lhs.b < rhs.b if lhs.a == rhs.a else lhs.a < rhs.a

# Perform the merge sort in-place
cuda.compute.merge_sort(keys, None, keys, None, compare_op, num_items=keys.size())
```

Explicit Fusion: Since iterators are "lazy", all computations are fused into a single kernel call here.

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