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Title: Data-Parallel Programming in PyTorch for Volumetric Radiation
Transport Solvers

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Data-Parallel Programming in PyTorch for Volumetric Radiation Transport Solvers

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Where else does the radiative transfer equation (RTE) appear?

Image credits (clockwise, from top left): Morrical et. al. 2019 (data from TACC, UT Austin), Woodcock et. al. 1965, [SCI Institute](#), Villefranque et. al. 2019, [ILM](#), Badal et. al. 2009, Liu et. al. 2001, Maeda et. al. 2019

OPEN MPI

👍 High performance

👎 Labor intensive

PyTorch

- 👍 High-level interface to the GPU
- 👍 Good distributed capability
- 👍 Ridiculously popular
- 👍 Backed by people with \$\$\$
- 👎 For ML, not scientific computing
- 👎 No low-level GPU programming

Data-parallel primitives

- Add
- SAXPY
- Scan
- Reduce
- Sort
- Rotate

Can we use **data-parallel primitives** in **PyTorch** for radiation transport?

1. How efficient are data-parallel primitives in PyTorch?
2. Can we implement a volume renderer with them in PyTorch?
3. How do we solve a scientific problem?

How efficient are data-parallel primitives in PyTorch?

Time for prefix-sum

Num. image elements vs. time to rotate image

Time for 50 repeated SAXPYs

Time for sort

Traditional volume rendering implementation

Analytic RTE solution:

$$I(D) = I_0 e^{-\int_0^D \kappa(t) dt} + \int_0^D g(s) e^{-\int_s^D \kappa(t) dt} ds$$

Traditional implementation

```
C = C_0
T = 1 - α[0]
for i=1→N:
    C = g[i] + (1-α[i])*C
end
```

Volume rendering with data-parallel primitives

$$I(D) = I_0 e^{-\int_0^D \kappa(t) dt} + \int_0^D g(s) e^{-\int_s^D \kappa(t) dt} ds$$
$$\approx I_0 \prod_{i=1}^N (1 - \alpha_i) + \sum_{i=1}^N g_i \prod_{j=i+1}^N (1 - \alpha_j)$$

Volume rendering with data-parallel primitives

$$I_0 \prod_{i=1}^N (1 - \alpha_i) + \sum_{i=1}^N g_i \prod_{j=i+1}^N (1 - \alpha_j)$$

$$= \text{mult_reduce} \left(\begin{bmatrix} 1 - \alpha_n \\ 1 - \alpha_{n-1} \\ 1 - \alpha_{n-2} \\ \vdots \\ 1 - \alpha_2 \\ 1 - \alpha_1 \end{bmatrix} \right) + \text{sum_reduce} \left(\begin{bmatrix} g_n \\ g_{n-1} \\ g_{n-2} \\ \vdots \\ g_2 \\ g_1 \end{bmatrix} \right) \odot \text{mult_scan} \left(\begin{bmatrix} 1 - \alpha_1 \\ 1 - \alpha_n \\ 1 - \alpha_{n-1} \\ 1 - \alpha_{n-2} \\ \vdots \\ 1 - \alpha_2 \end{bmatrix} \right)$$

Circular shift

Ours vs. OpenVKL vs. ParaView

Ours

OpenVKL

ParaView

Ours vs. OpenVKL vs. ParaView

Renderer	Frames / sec. (Higher is better)	Sec. / frame (Lower is better)
Ours, orthographic (GPU)	17.7	0.0564
Ours, perspective (GPU)	4.76	0.210
ParaView (GPU)	67.61	0.0148
OpenVKL (CPU)	19.2	0.052

Volume rendering integral & photoionization rate equation

$$I(D) = I_0 e^{-\int_0^D \kappa(t) dt} + \int_0^D g(s) e^{-\int_s^D \kappa(t) dt} ds$$

$$\Gamma_{\text{local}}(r) = \frac{1}{4\pi r^2} \int_{v_{\text{th}}}^{\infty} \frac{L_\nu \sigma_\nu e^{-\tau_\nu(r)}}{h\nu} d\nu$$

C²-Ray Algorithm Implementation: Preliminary Results

Conclusion

1. How efficient are data-parallel primitives in PyTorch?
 2. Can we implement a volume renderer with them in PyTorch?
 3. How do we solve a scientific problem?
1. Data-parallel primitives are reasonably fast in PyTorch, although rotation and sort are suboptimal.
 2. We absolutely can implement reasonably efficient volume renderer in PyTorch.
 - a. It is not quite as fast as a native GPU renderer due to rotation being slower than native CUDA code.
 3. We're learning how to solve a scientific problem
 - a. We found a well-defined theoretical relationship between volume rendering and what the C²-Ray code is doing.
 - b. We have encouraging initial test results, despite running into a convergence problem.

Fin.

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Convergence and optical thickness

Linear interpolation in pytorch

veeresh_d

Jan 16

Hi all.

I am new to pytorch. is there any interpolation (linear) function that is similar to the `np.interp` function.

Please let me know if you need any details? Thanks in advance.

Reply

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Jan 16

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25d

6

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albanD

Jan 16

Hi,

I'm afraid there is none.

If you're fine with a non-differentiable, cpu-only implementation, you can use the numpy one as a workaround: `res = torch.from_numpy(np.interp(x.numpy(), fx.numpy(), fp.numpy()))`.

1

Reply

6 MONTHS LATER

sbarratt Shane Barratt

25d

I just wrote a package that implements this (GPU-compatible & differentiable).

https://github.com/sbarratt/torch_interpolations 18

1 ❤️

↩ Reply

How efficient are data-parallel primitives in PyTorch?

Time for sort, scan, add, rotate

Scan Benchmark

Time for prefix-sum

SAXPY Benchmark

Time for 50 repeated SAXPYs

Sort Benchmark

Time for sort

Segmented reduce benchmark

Time for reduce (8 segments)

Image Rotation Benchmark

Num. image elements vs. time to rotate image

Scan, sort, rotation time as ratio of SAXPY time

Ratio of scan, sort, rot time to SAXPY time

Profiler output

Volume rendering with data-parallel primitives

TorchScript ?