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Memory-Aware Scheduling of Tasks Sharing Data on Multiple GPUs

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March 23, 2023
Why focus on memory-aware scheduling?

GPUs are quick but have a limited memory

They share the same PCI bus with limited bandwidth
Example with 2D grid dependencies

GOALS:

- **Balancing** tasks among GPUs → Reduce total execution time
- **Ordering** tasks inside each GPU → Reduce data transfers
- Having a **generic** scheduler → Efficient with any application or memory limitation
Dynamic scheduler of STARPU: DMDAR

**Strategy**
Schedule tasks so their completion time is minimal based on computation + communication times

+ **Ready** reordering heuristic on $\text{GPU}_k$
From the list $L$ of tasks allocated on $\text{GPU}_k$, it will search the task $T \in L$ requiring the fewest data transfers
Data-Aware Reactive Task Scheduling: DARTS

The scheduling is done by $\text{GPU}_k$ when it needs new tasks.

- Find $D_{opt} \in data\text{NotInMem}_k$ such that the number of tasks depending on $D_{opt}$ and on other data already in memory is maximum (if there is a tie: choose with transfer time, priority of the associated tasks and most total unprocessed task)

- $\text{plannedTasks}_k \leftarrow$ set of unprocessed tasks depending only on $D_{opt}$ and on other data already in memory

Our eviction policy: LUF (Least Used in the Future)

- Try to evict a data not useful for any task already in the GPU’s buffer.

- Try to evict a data used by a minimal number of tasks in the set of task planned by the scheduler.
2D matrix multiplication with 2 Tesla V100 GPUs

![Graph showing performance of different algorithms with varying working set sizes. The x-axis represents the working set size in MB, and the y-axis represents GFlop/s. The graph compares DARTS+LUF, DMDAR, DARTS, and EAGER algorithms. The x-axis is labeled as 'Working set (MB)' and the y-axis as 'GFlop/s.' Notable points include 'A and B fits in cumulated memory' and 'B fits in cumulated memory.' The legend is shown at the bottom right of the graph.]
Amount of data transfers on the 2D matrix multiplication with 2 Tesla V100 GPUs
Cholesky decomposition with 2 GPUs

![Graph showing performance metrics with working set vs GFlop/s for different scheduling algorithms: DARTS+LUF, DMDAR, PaRSEC, EAGER. The graph indicates performance optimization across different working set sizes.]
Cholesky decomposition with 8 GPUs

- All data fit
- GFlop/s max
- Working set (MB)
- GFlop/s
- DARTS+LUF
- DMDAR
- PaRSEC
- EAGER
LU with 8 GPUs

![Graph showing performance comparison between DARTS+LUF, DMDAR, and EAGER]

- All data fit
- GFlop/s max
- Working set (MB)
- GFlop/s
- DARTS+LUF
- DMDAR
- EAGER

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Conclusion

Limiting data movements is crucial

→ New strategy: DARTS, focused on data movement

Tested on 2D matrix multiplication, Cholesky decomposition, LU, GEMM and sparse matrix multiplication → DARTS can achieves good performance when the memory is not constrained and always get very good performance when it is a scarce resource

Areas for improvement

- Improve computational complexity. It’s holding us back to get good performances on Gemms and large matrices of the outer product
- Manage multiple MPI nodes
- Export it to other out-of-core applications. DARTS is not specific to GPUs!
If you have an open postdoc position contact me :) 

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Source: Analysis of Dynamic Scheduling Strategies for Matrix Multiplication on Heterogeneous Platforms - Marchal - Beaumont
Sparse 2D matrix multiplication without memory limitation (32GB by GPU) with 4 Tesla V100 GPUs

- No memory constraint
- DARTS produces a **processing order that best distributes transfers over time**