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Memory-Aware Scheduling of Tasks Sharing Data on Multiple GPUs

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

- Find $D_{\text{opt}} \in \text{dataNotInMem}_k$ such that the number of tasks depending on $D_{\text{opt}}$ 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 $D_{\text{opt}}$ 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

Working set (MB) vs. GFlop/s

- DARTS+LUF
- DMDAR
- DARTS
- EAGER

A and B fits in cumulated memory
B fits in cumulated memory
GFlop/s max
Amount of data transfers on the 2D matrix multiplication with 2 Tesla V100 GPUs
Cholesky decomposition with 2 GPUs

Working set (MB) vs GFlop/s for different memory-aware scheduling algorithms:
- DARTS+LUF
- DMDAR
- PaRSEC
- EAGER

Maximum GFlop/s (GFlop/s max) is achieved at different working set sizes for each algorithm.
Cholesky decomposition with 8 GPUs

![Graph showing performance of different schedulers (DARTS+LUF, DMDAR, PaRSEC, EAGER) across varying working set sizes (MB) and GFlop/s. The x-axis represents the working set size in MB, and the y-axis represents the GFlop/s performance. The graph highlights the performance of each scheduler at different working set sizes, with DARTS+LUF, DMDAR, PaRSEC, and EAGER represented by distinct markers and line styles.]
LU with 8 GPUs

![Graph showing performance metrics for different algorithms with varying working set sizes.](image)
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 achieve 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**