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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 GPU$_k$
From the list $L$ of tasks allocated on 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 $D_{opt} \in \text{dataNotInMem}_k$ 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

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Memory-Aware Scheduling

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Amount of data transfers on the 2D matrix multiplication with 2 Tesla V100 GPUs
Cholesky decomposition with 2 GPUs

![Graph showing performance comparison between different algorithms]

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

![Graph showing performance of different algorithms (DARTS+LUF, DMDAR, EAGER) with working set size and GFlop/s.](image)

- **GFlop/s max**: The maximum GFlop/s achieved with all data fit.
- **Working set (MB)**: The size of the working set in megabytes.
- **GFlop/s**: The GFlop/s performance at different working set sizes.

Legend:
- DARTS+LUF
- DMDAR
- EAGER

- **All data fit**: Indicating the working set size where all data fits into memory.

Memory-Aware Scheduling - March 23, 2023
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 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**

![Graph showing performance comparison of different scheduling strategies](image)