Memory-Aware Scheduling Of Tasks Sharing Data On Multiple GPUs
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To cite this version:
Maxime Gonthier, Loris Marchal, Samuel Thibault. Memory-Aware Scheduling Of Tasks Sharing Data On Multiple GPUs. ISC 2023 - ISC High Performance 2023, May 2023, Hamburg, Germany. Lecture Notes in Computer Science. hal-04090595

HAL Id: hal-04090595
https://inria.hal.science/hal-04090595
Submitted on 5 May 2023

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Motivation: Extract peak performance from GPUs

- Scientific application uses a huge quantity of data
- GPUs can calculate quickly but their memory are limited
- The PCI bus becomes a bottleneck when large amounts of data need to be loaded

Frameworks and objectives

- Indepedent tasks sharing data
- Same size data
- Multiple GPUs with limited memory

Algorithms from the state of the art

- Using (hyper-)graph partitioning: hMETIS
  - Hypergraph graph = Represents a data being shared by multiple tasks
  - hMETIS produces subsets of task that maximize the amount of edges (data shares) inside each subset
  - We add dynamic reordering and task stealing to improve performance
  - EAGER
    - Process tasks in the order in which it receives them → our baseline
  - Deque Model Data Aware Ready (DMDAR): Schedules tasks where their completion times are expected to be minimal. Uses a ready strategy to favor tasks whose data has already been loaded into memory.

A novel strategy: Data-Aware Reactive Task Scheduling (DARTS)

- Task flow
  - (1). DARTS fills Planned Tasks
  - (2). Some tasks are popped by Task Buffer and start to be prefetched
  - (3). If the GPU is idling, a task is popped from Task Buffer
  - (4). After an eviction, tasks in Planned Tasks can be removed

Experimental evaluations on independent tasksset

- Tesla V100 GPUs with a 12000 MB/s PCI bandwidth
- GPU memory limited to 500 MB to better distinguish the performance even on small datasets
- 10 runs per experiment (deviation < 2%)

- hMETIS suffers from a large scheduling cost
- DMDAR suffers from a conflict between prefetches and evictions
- DARTS+LUF stays close to the asymptotic goal !

DARTS nicely overlaps communications and computations

- hMETIS suffers from a large scheduling cost
- DMDAR can be used with a reduced complexity (DARTS+OPTI) by stopping the search for the optimal data earlier.
- Even without memory limitation, DARTS outperforms DMDAR

Experimental evaluations with dependencies

- When choosing the optimal data with dependencies, DARTS takes into account the transfer time, priority and length of task associated with each data.
- DARTS achieves better performances once the memory is a constraint (on the right of the green dotted line) and behaves as DMDAR when the memory is not limited (on the left). It also greatly reduces data transfers. DARTS outperforms the scheduler from PaRSEC, a state-of-the-art runtime.

Summary and conclusion

- High-performance computing applications, like weather and climate forecasting, have an increasing demand in computer power
- GPUs have a large computation power but have a limited memory. This, coupled with the share of a single PCI express bus by multiple GPUs induce a large amount of data transfers which reduces performance ⇒ Limiting data movement is crucial to extract the most out of GPUs
- We provide a new algorithm (DARTS) and a new eviction policy (LUF) focused on data locality
- DARTS+LUF achieves good performance because it:
  - Limits data transfers thanks to the finding of an optimal data and an adapted eviction policy
  - Overlaps communication and computations by distributing transfers over time
  - Can be used with a reduced complexity
  - Can deal with priorities
- Areas for improvement:
  - Manage multiple MPI nodes
  - Use other out-of-core applications (DARTS is not specific to GPUs)

You can learn more about me on my website.