Task Mapping for Non-contiguous Allocations

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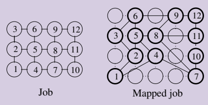
Task Mapping

- Assign job tasks to allocated nodes
- Close communicating tasks use fewer links
  - Preserves bandwidth, lessening interference between jobs (Applications have seen a 1.64-times speedup from improved mapping [4])
  - Potentially saves power

We map <u>common job communication pattern</u> (stencil) onto <u>practical allocations for Cray X</u> (non-contiguous mesh nodes)



Previous work either
- Assumes contiguous allocation (e.g. [6])
  - Not useful w/ non-contiguous allocation (e.g. on Cray XE)
- States problem as graph embedding (e.g. [5])
  - Very general, but loses geometric information (coords)

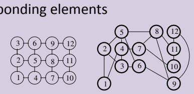
Algorithms

Rotations
- Rotate job so relative order of dimension lengths matches dimensions of bounding box of nodes
- Applied to all algorithms except Baseline and Grouping

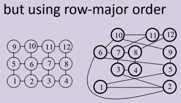
Baseline (provided by ALPS and Moab)
- Number cores in alloc. order and tasks in row-major order
- Map corresponding elements

Grouping [1]
- Baseline after grouping tasks into 2x2x4 blocks

ColMajor
- Number tasks and cores in column-major order
- Map corresponding elements

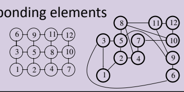


RowMajor
- As ColMajor, but using row-major order

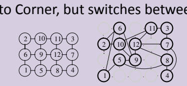


Ordered
- Try different linear orders (inc. ColMajor and RowMajor)
- Take whichever gives lowest average hops

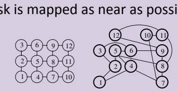
Corner (generalizes "Expand from corner" [3] w/ rotations)
- Number tasks and cores based on distance from (0,0)
- Map corresponding elements



AllCorners (generalizes "Corners to center" [3] w/ rotations)
- Similar to Corner, but switches between corners

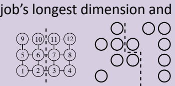


Overlay
- Identifies desired location for each task
- Lower left corner task desires lower left corner core
- Other tasks relative to this
- Each task is mapped as near as possible to desired location

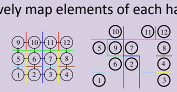


TwoWayOverlay
- Similar to Overlay, but switches between opposite corners

RCB
- Bisects job's longest dimension and bisect cores w/ same one



- Recursively map elements of each half



- [5] also has bisection heuristic, but with general graphs
  - Loses geometric relationship between recursion levels so doesn't perform as well in our setting

Experiments

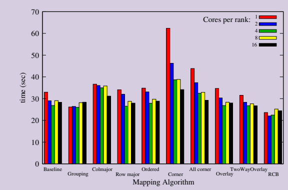
Machine: Cielo – Cray XE6
- 8,944 compute nodes (2 sockets/node, 8 cores/socket)
- Gemini 3D torus in 16x12x24 (XYZ) topology
  - 6.47x4.38x4.38 (XYZ) TB/s bisection bandwidth
- #22 on June 2013 Top500 list

Job configurations
- 16-64K cores, with rectangular prism job shape
- Between 1 and 16 cores per MPI rank (MPI + OpenMP)

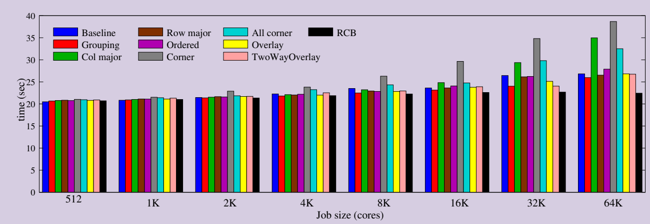
Application: miniGhost "mini application" [2]
- Boundary exchange using stencil computation
- Modeled after CTH, a multi-material, large deformation, strong shock wave, solid mechanics code
- Gives similar scaling as CTH, including relative performance improvement for remapping

Results averaged over 5 runs

Number of cores per MPI rank
- Tuning option in miniGhost (changes number of ranks)
  - More ranks means more messages, but smaller
  - More ranks also slows collective operations
- Worst mappers favor 16 cores/rank
  - Fewer messages helps network-bound runs
- Better mappers perform best at intermediate values
  - We focus on 4 cores/rank; also favored in previous work [1]



Time for 64K-core job as a function of cores/rank



Time as a function of job size (4 cores/rank)

Overall results
- RCB is consistently the best mapper
  - 4 cores/rank: 16% ave. improvement at 64K (12.8-18.6% per run)
  - Better w/ other cores/rank: 24.1% at 2 and 28.4% at 1
  - Also most consistent: Baseline running time had multi-second std. deviations while RCB always ≤ 0.6 seconds
- Best overall performance: RCB with 2 cores/rank (Best in 17 of 20 trials at 8K+ cores (5 runs of 4 sizes))

Rotations and correlations to enable future simulations
- Rotation step improves ~60% of runs (ave. benefit 1-6%)
- Average hops between communicating tasks correlates with running time (Spearman rank test; significance level 0.05 or better for 1K+ core jobs)
  - Small jobs affected by hop between sockets at node
  - Allowed trace-based simulations that confirmed relative quality of mapping algorithms

References

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